

**Variations in Abundance of Larval
Anisakines, Sealworm (*Pseudoterranova
decipiens*) and Related Species, in
Eastern Canadian Cod and Flatfish**

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ABSTRACT

McClelland, G., R. K. Misra and D. J. Martell. 1985. Variations in abundance of larval anisakines, sealworm (*Pseudoterranova decipiens*) and related species, in eastern Canadian cod and flatfish. Can. Tech. Rep. Fish. Aquat. Sci. No. 1392. xi + 57 p.

Surveys of larval anisakine infections in cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), gray sole (*Glyptocephalus cynoglossus*) and yellowtail flounder (*Limanda ferruginea*) revealed that sealworm, *Pseudoterranova* (*Phocanema*) *decipiens*, was most abundant in fish from the southeastern Gulf of St. Lawrence (NAFO division 4Tg), Breton Shelf (4VN), eastern Scotian Shelf (4VS-4W), northeastern Gulf of Maine (4Xq) and Lower Bay of Fundy (4Xrs). Sealworm had also become increasingly numerous in cod and flatfish from southern Newfoundland (3P-30), the northern Gulf of St. Lawrence (4R-4S) and the southwestern Scotian Shelf (4Xnop). *Anisakis simplex* and *Contracaecum osculatum* were most abundant in cod and plaice from the Whale Bank (30b) and the northeastern Gulf of St. Lawrence (4R-4Sv). *A. simplex* was least abundant in cod and flatfish from the Lower Bay of Fundy (4Xrs) and Georges Bank (5ZEj) while *C. osculatum* was seldom found in fish from the Scotian Shelf and southwestern Nova Scotia (4VS, 4W, 4X and 5ZEj). Sealworm occurred primarily (68%-100%) in the fillets, *A. simplex* (86%-100%) and *C. osculatum* (>99%) on visceral organs and mesenteries. *A. simplex* larvae were frequently detected in the flesh of heavily infected cod and plaice from southern and western Newfoundland, but they were usually concentrated (>80%) in the napes. A significant majority of the larval anisakines (*P. decipiens* and *A. simplex*) in the flesh of cod occurred in the left side (nape and fillet) of the body; nematodes in the left side outnumbered those in the right side 1.5:1 (1.2:1 - 2.7:1). Geographical variations in abundance of sealworm in groundfish appear to be related to the distribution of the gray seal (*Halichoerus grypus*), the principal final host of *P. decipiens*. The increasing severity and extent of the worm problem in eastern Canadian fisheries could be attributable to the recent growth and redistribution of the northwest Atlantic gray seal population. This study shows that abundances and distribution of larval sealworm in eastern Canadian fisheries can be monitored most efficiently by surveying infestations in the fillets of small (31 cm-40 cm in length) American plaice.

Key words: Sealworm, *Pseudoterranova* (*Phocanema*) *decipiens*; *Anisakis simplex*; *Contracaecum osculatum*; nematodes; larval parasitic anisakine; cod, *Gadus morhua*; American plaice, *Hippoglossoides platessoides*; gray sole, *Glyptocephalus cynoglossus*; eastern Canada; prevalence; abundance; density; variations; geographic; and host length.

RÉSUMÉ

McClelland, G., R. K. Misra and D. J. Martell. 1985. Variations in abundance of larval anisakines, sealworm (*Pseudoterranova decipiens*) and related species, in eastern Canadian cod and flatfish. Can. Tech. Rep. Fish. Aquat. Sci. No. 1392. xi+57p.

Des études sur les infections par des larves d'anisakines chez la morue (*Gadus morhua*), chez la plie canadienne (*Hippoglossoides platessoides*), chez la plie grise (*Glyptocephalus cynoglossus*) et chez la limande à queue jaune (*Limanda ferruginea*) ont révélé que le ver de phoque, *Pseudoterranova* (*Phocanema*) *decipiens*, était le plus abondant dans le poisson du sud-est du golfe du Saint-Laurent (division 4Tg de l'OPANO), du plateau Breton (4VN), de l'est du plateau Scotian (4VS-4W), du nord-est du golfe du Maine (4Xq) et de la partie inférieure de la baie de Fundy (4Xrs). Le ver de phoque devient de plus en plus nombreux chez la morue et le poisson plat du sud de Terre-Neuve (3P-30), du nord du golfe du Saint-Laurent (4R-4S) et du sud-ouest du plateau Scotian (4Xnop). *Anisakis simplex* et *Contracaecum osculatum* étaient les plus abondants chez la morue et la plie du banc Whale (30b) et du nord-est du golfe du Saint-Laurent (4R-4Sv). *A. simplex* était le moins abondant chez la morue et le poisson plat de la partie inférieure de la baie de Fundy (4Xrs) et du banc Georges (5ZEj), tandis que *C. osculatum* est rare chez le poisson provenant du plateau Scotia et du sud-ouest de la Nouvelle-Ecosse (4VS, 4W, 4X et 5ZEj). Le ver de phoque est surtout présent dans les filets (68% - 100%), tandis qu'*A. simplex* (86% - 100%) et *C. osculatum* (99%) sont observés surtout dans les viscères et les mésentères. Des larves d'*A. simplex* ont été observées fréquemment dans la chair de morues et de plies fortement infestées provenant du sud et de l'ouest de Terre-Neuve, mais ces larves étaient concentrées dans la nuque (80%). Dans la chair de morue, la proportion des larves d'anisakines (*P. decipiens* et *A. simplex*) était plus importante du côté gauche (nuque et filet) du corps; si on compare le nombre de nématodes trouvés dans le côté gauche par rapport au nombre trouvé dans le côté droit, on obtient un rapport de 1,5/1 (1,2/1 - 2,7/1). Les variations géographiques dans l'abondance du ver de phoque chez le poisson de fond semblent être liées à la répartition du phoque gris (*Halichoerus grypus*), le principal hôte définitif de *P. decipiens*. Le problème lié à la présence des vers dans les pêcheries de l'est du Canada, problème qui croît en gravité et en étendue, pourrait être attribuable à la croissance et à la redistribution récentes de la population de phoques gris de nord-ouest de l'Atlantique. La présente étude indique que la manière la plus efficace de vérifier l'abondance et la répartition des vers de phoque au stade larvaire dans les pêcheries de l'est du Canada consiste à étudier les infestations dans les filets de plie canadienne de petite taille (31 cm-40 cm de longueur).

INTRODUCTION

Recent surveys of larval anisakine infections in cod (*Gadus morhua*), plaice (*Hippoglossoides platessoides*), gray sole (*Glyptocephalus cynoglossus*) and yellowtail flounder (*Limanda ferruginea*) from the southern Gulf of St. Lawrence (4T)¹ and the Breton (4VN) and Scotian (4VS-4W) shelves have shown that abundances of the nematodes vary significantly with body length and geographic origin of the hosts (McClelland et al. 1983a and b). These surveys also indicated that sealworm, *Pseudoterranova* (*Phocanema*) *decipiens*, larvae had become more numerous in the fillets of southeastern Gulf, Breton and Scotian Shelf cod and flatfish than previously reported by Scott and Martin (1957) and Templeman et al. (1957). The growing abundance of the parasite was particularly evident in fish from the Sable Island Bank complex (4W).

The first objective of the present study was to extend the survey of larval anisakines to cod and flatfish from the southwestern portion of the Scotian Shelf (4W1 to 4Xp), the northeastern Gulf of Maine and lower Bay of Fundy (4Xqrs) and George's Bank (5ZEj). A second objective was to provide an instantaneous picture of the geographical distribution of sealworm in eastern Canadian groundfish by using American plaice in the 31-cm to 40-cm length range as indicator hosts (see McClelland et al. 1983b).

MATERIALS AND METHODS

COLLECTION AND EXAMINATION OF SAMPLES

Cod and flatfish samples were collected during Department of Fisheries and Oceans (DFO) groundfish, shrimp and scallop surveys and from commercial dragger, longline and gill-net fisheries. Samples from the southwestern Grand Banks (30b), the northern Gulf of St. Lawrence (4R-4Sv) and southwestern Nova Scotia (4W1, 4X and 5ZEj) were selected according to an orthogonal sampling design by which cod were stratified into eight (340, 41-45, 46-50, 51-55, 56-60, 61-65, 66-70, 271 cm) and flatfish into seven (330, 31-35, 36-40, 41-45, 46-50, 46-50, 251 cm) length groups containing uniform numbers of fish. Data from earlier surveys (McClelland et al. 1983a and b) were used to estimate appropriate sample sizes (see Section 9:8, Sokal and Rohlf 1969). For stratified samples, 30 ± 10 fish were selected in each length group and additional American plaice were collected to bring the total numbers in the 31-cm to 40-cm length range in each sample to 150 ± 50. Plaice samples from Labrador (2J), northeastern Newfoundland (3K and 3L), the Grand Banks (3L, 3N and 3O), southern Newfoundland (3P), the Gulf of St. Lawrence (4R, 4S and 4T), the Breton

Shelf (4VN) and the eastern portion of the Scotian Shelf (4VS-4W) were limited to fish in the 31-cm to 40-cm length range (n=150 ± 50).

It was not possible to conform to the sampling design in many cases. This was particularly true off southwestern Nova Scotia where commercial cod and flatfish bycatches were exceptionally light and fish were scarce or lacking in some length strata. Fish collected for the investigators by commercial fishermen were usually of random length. The fact that many samples collected on DFO research cruises failed to comply with the sampling design was attributable to a scarcity of fish at predetermined sampling stations and/or the brevity of the sets (15 min.).

Commercial samples were stored on ice and examined in the "fresh" condition, whereas frozen samples from DFO surveys were thawed for 24-48 hours at room temperature prior to inspection. The fish were measured, weighed, gutted, sexed and filleted. Fillets and napes were examined by systematic destruction of the flesh (Power 1961), with all nematodes found therein being identified and counted. Nematodes found in the visceral organs and mesenteries of cod and flatfish from areas 30, 4R, 4Sv, 4W1, 4X and 5ZEj were also identified and counted. Some nematodes from the visceral mesenteries of cod, plaice and capelin (*Mallotus villosus*)² were preserved in 5% glycerine in 70% alcohol and cleared in glycerine for morphological and morphometric studies.

SPECIFIC IDENTITIES OF LARVAL ANISAKINES

The specific identities of larval anisakines found in this study were verified by encouraging fresh, viable larvae from the viscera and flesh of cod to mature *in vitro*. Larvae were reared in static culture at 35°C by using a medium and gas phase developed for *in vitro* maturation of *Ascaris suum* (Douvres and Urban 1983). *Pseudoterranova* (*Phocanema*)³ sp. and *Anisakis* sp. reached maturity; the adult nematodes were identified as *P. decipiens* and *A. simplex*, respectively. Ninety-five percent of *Contracaecum* (*Phocascaris*) sp. larvae (n=325) survived three weeks *in vitro* and developed to the fourth stage or beyond, but the cultures were destroyed by bacterial contamination during the fourth week and none of these nematodes reached maturity. Nevertheless, larvae of this latter species of nematode were identified as *Contracaecum osculatatum* by the following criteria: the striking morphological and morphometric similarity

1. Northwest Atlantic Fisheries Organization (NAFO) Division (Fig. 1).

2. Fresh and frozen capelin were collected from the Avalon Peninsula (3L), Newfoundland, in June, 1984.

3. Gibson (1983) considers *Pseudoterranova* (Mozgovoi in Skrjabin et al. 1951) and *Phocanema* (Myers 1959) synonymous, with the former having date priority.

of the larvae* to known third-stage larvae of *C. osculatum* reared in vitro by McClelland and Ronald (1974b), and the similarity of the geographical distribution of these larval nematodes to the range of the principal definitive host of *C. osculatum*, the harp seal (*Phoca groenlandica*).

STATISTICAL ANALYSES

Quantitative terms used throughout this report are defined as follows (Margolis et al. 1982; Arthur et al. 1982).

Prevalence = Number of fish infected ÷ number of fish examined (expressed as a percentage).

Abundance = Total number of parasites in a sample of fish ÷ number of fish (infected and uninfected) in the sample = Mean number of parasites per fish.

Density (in fillets) = Total number of parasites found in the fillet of sample of fish ÷ by the total weight of sample = Average number of parasites per unit fillet weight (per kg).

Statistical methods employed in the present study were similar to those used in studies of larval anisakines in AT, 4VN, 4VS and 4W cod and flatfish (McClelland et al. 1983a and b) and data from the earlier studies were analyzed together with more recent data from 30, 4R-4Sv, 4W1-4X and 5ZEj cod and flatfish herein. As frequency distributions of worm counts were invariably skewed to the right (Figs. 6, 7, 8 and 18), counts of larval anisakines in individual fish were transformed by $\log_{10}(n+1)$ (Platt 1975). Significance of geographical variations in abundance of sealworm (*P. decipiens*) in the fillets of American plaice (31 cm to 40 cm in length) was tested by one-way ANOVAs (SAS 1982). Variations in abundance of larval anisakines related to geographic origin (sample) and length of the host in stratified cod and flatfish samples were analyzed by two-way Type III ANOVAs.

The following steps were taken to eliminate blank cells from two-way ANOVAs of parasites in stratified cod and flatfish samples: Cod 266 cm in length were included in a single length stratum and cod samples from Cheticamp (November 1980) and East Bar, Sable Island (September 1982), which lacked fish 261 cm in length, were deleted; seven length strata (above) were retained for plaice but three samples (H-13, -14 and -15, Table 7) from the Browns-LaHave-Roseway area were treated as a single sample and small, incomplete samples from West Browns Bank (H-21) and Emerald Basin (H-22) were deleted; finally, gray sole 535 cm in length were included in a single length stratum.

4. From the visceral mesenteries of Whale Bank (30) cod and capelin from the Avalon Peninsula, Newfoundland (3L).

Individual samples in one- or two-way ANOVAs were compared by fixed-factor design - a priori contrasts. When samples from discrete geographical areas did not differ significantly in respect to nematode abundances, they were combined and contrasted with individual samples or combined samples from adjacent areas. An alternate method, in which adjustments were made for heterogeneity in variance, was employed in one-way contrasts of sealworm abundances in 31-cm to 40-cm plaice. Rather than being tested against the error of the ANOVA, contrasts were analyzed by a procedure in which means were weighted by the reciprocals of their estimated variances and compared by X^2 tests (Li 1964; Armitage 1971). As sample means with zero variance could not be weighted, worm-free samples from 3K, 3L and 3N (Table 12) were compared with infected samples from adjacent areas by inference of T -tests, which determined whether the mean worm counts in the infected samples were significantly greater than zero. Adjustments for heterogeneity of variance were not possible in contrasts of samples from two-way ANOVAs because of the existence of significant interactions between sources of variation.

Levels of significance for one-way contrasts were set by the Bonferroni method, where $P \leq \frac{0.05}{K}$ for K contrasts (Morrison 1976). It was pointless, however, to estimate confidence levels for two-way contrasts by this method. Given the unbalanced design of two-way ANOVAs and the impracticability of adjusting for heterogeneity of variance, two-way contrasts would be prone to results of false significance (Underwood 1981, McClelland et al. 1983a). As a consequence, we arbitrarily chose a conservative confidence interval ($P \leq 0.001$).

Three-way Type-III ANOVAs in which body side, body length and geographic origin of host were sources of variation, were used to compare nematode abundances in the left and right sides of the fillet. The within-cell sums of squares for two-way classifications were examined in order to determine the appropriate error terms. The sums of squares for these ANOVAs were composed of squares of deviations related to variations among fish (sample, length and sample X length) and those related to the interaction of fish and body side (side, sample X side, length X side and length X sample X side). As the mean squares for these two components differed significantly ($P \leq 0.0001$) in each case, the sums of squares could not be pooled; and the larger mean squares, those for variations among fish, were used as error terms in the ANOVAs.

Geographical distributions of *P. decipiens* in cod and American plaice were compared by using paired samples of the two host species collected during present and earlier (McClelland et al. 1983a and b)

surveys. Because of disparities in sample and cell size, direct analyses of geographical correlations in sealworm abundance in cod and plaice were not possible and the following approach was employed. Plaice samples were ranked in ascending order of mean transformed sealworm counts for fish 31 cm - 40 cm in length. Each mean worm count was weighted by the reciprocal of its variance and, following the example of Snedecor and Cochran (1980), significance of the regression of weighted mean on rank was tested. Worm count/rank regressions for cod 50, 51-70 and 271 cm in length were subsequently analyzed with cod samples being assigned the same ranks as plaice samples from corresponding locations. Where variances for cod and plaice regressions differed, regression coefficients were compared by a X^2 method (Armitage 1971).

RESULTS

LARVAL ANISAKINES IN COD

Pseudoterranova (Phocanema) decipiens

In the 1983-84 survey, sealworm were most numerous in cod from Emerald Bank (4W1) and Grand Manan Basin (4Xrs) but moderately heavy infections were also detected in Roseway Bank (4Xo) and Brown's Bank (4Xp) cod (Table 1; Figs. 3 and 6). Sealworm infestations in cod from the northeastern Gulf of St. Lawrence (4R-4Sv) and Georges Bank (5ZEj) were light, but parasite densities in the fillets (1.29/kg and 1.49/kg, respectively) nevertheless exceeded the government standard for maximum number permissible (0.73/kg). Sealworm densities in the fillets of Whale Bank (30b) and Fundian Channel (5ZEj) cod (0.40/kg and 0.62/kg, respectively) were within the government standard.

Prevalence and abundance of sealworm increased with host length, but there was no consistent trend for worm densities in fillets (Table 1; Fig. 9). Sealworm densities in fillets appeared to increase with host length in northeastern Gulf, Roseway and Brown's Bank samples; however, in Lower Fundy, Fundian Channel and Georges Bank samples, the greatest sealworm densities occurred in the fillets of smaller cod.

While the majority of sealworms occurred in the fillets, many were also found in the napes and in the body cavity, encysted on visceral organs and mesenteries (Table 2). The proportion of sealworm in the napes and body cavity increased with the size of the host; in Whale Bank and northeastern Gulf cod 271 cm in length, nearly a third of the parasites were in the napes and body cavity. The proportion of worms in the body cavity was much higher in Newfoundland cod (13.25%) than it was in cod from southwestern Nova Scotia (2.70%).

The majority of sealworms in the flesh occurred on the left side of the body and

this was apparent for both fillets and napes (Table 3). According to a three-way ANOVA, however, the disparity in sealworm abundance between left and right side was not highly significant ($P=0.025$) (Table 4). As indicated by the nonsignificance of interactions (with sample and host length), the trend to greater abundance of sealworm in the left side of cod did not vary with geographic origin or host length.

A two-way analysis of stratified cod samples collected during the present survey (30b, 4R-4Sv and 4W1-4X-5ZEj) and during earlier surveys (4T-4Vn and 4Vs-4W) indicates that variations in sealworm abundance with geographic origin (sample) and length of host were highly significant (Table 5). The interaction of sampling and length effects was also highly significant. Contrasts (Table 6) reveal sealworm abundance was significantly greater ($P=0.0004$) in cod from the northeastern Gulf (4R-4Sv) than it was in Whale Bank (30b) cod; northeastern Gulf cod, however, had significantly fewer sealworms than did cod from the southern Gulf (4T) offshore ($P=0.0008$). Sealworm were less numerous ($P<0.0001$) in Emerald Bank (4W1) cod than in Western Bank (4Wj) cod, but there were no significant differences in sealworm abundance among Emerald, Roseway (4Xo) and Brown's Bank (4Xp) samples. The two cod samples from 5ZEj (George's Bank and Fundian Channel) did not differ significantly in respect to sealworm abundance ($P=0.2346$) but 5ZEj cod had lighter infections than did Brown's Bank cod ($P<0.0001$).

Anisakis simplex

Cod samples collected from Whale Bank (30b) and the northeastern Gulf (4R-4Sv) during the current survey were heavily infected with A. simplex larvae (Table 1; Figs. 4 and 7). Among samples from southwestern Nova Scotia, A. simplex were most numerous in Emerald Bank (4W1) cod and least abundant in cod from the Grand Manan Basin (4Xrs), Fundian Channel and George's Bank (5ZEj). Prevalence and abundance of the parasite increased with host length in each sample (Fig. 10).

Larvae of A. simplex were found primarily in the body cavity, where they were encysted on the liver, visceral mesenteries (particularly around the pyloric caeca) and peritoneum (Table 2). In heavily infected Newfoundland (30b, 4R-4Sv) cod, 9.45% of A. simplex were found in the flesh but this proportion varied inversely with host length, from 13.75% in fish 50 cm in length to 3.47% in fish 271 cm in length. Cod from southwestern Nova Scotia (4W1, 4X-5ZEj) not only had far fewer A. simplex overall but the relative proportions of these parasites in the flesh were much lower; 4.67% were found in the flesh of fish 50 cm in length, 0.74% in the flesh of those 271 cm in length. Nematodes in the napes outnumbered those in

the fillets by 5:1 in Newfoundland cod and 4:1 in Nova Scotia cod.

As noted above for sealworms, *A. simplex* larvae were more numerous in the left side (nape & fillet) than in the right side of the body (Table 3). A three-way ANOVA indicates that the disparity in worm abundance between left and right sides of cod was highly significant, both as main effect ($P \leq 0.0001$) and in interaction with the sampling effect ($P = 0.001$) (Table 4).

A two-way analysis of all stratified cod samples from eastern Canada (30b, 4R-4Sv, 4T-4Vn, 4VS-4W and 4X-5ZEj) reveals that variations in abundance of *A. simplex* larvae with sample and host length were highly significant and that the interaction of sampling and host length effects was also highly significant (Table 5). As indicated by contrasts (Table 6), abundance of *A. simplex* in cod from the northeastern Gulf (4R-4Sv) was significantly greater than abundances found in Whale Bank (30b) ($P \leq 0.0001$) or southern Gulf (4T) cod ($P \leq 0.0001$). Roseway Bank (4Xo) cod had fewer *A. simplex* than Emerald Bank (4Wl) cod ($P = 0.0015$) but were more heavily infected than cod from Browns Bank (4Xp) ($P \leq 0.0001$). Cod from the Grand Manan Basin (4Xrs), the Fundian Channel and Georges Bank (5ZEj) were, in turn, infected with fewer worms than Browns Bank fish ($P \leq 0.0001$). Variations in abundance of *A. simplex* among Lower Fundy and 5ZEj samples were not significant ($P = 0.6066$).

Contracaecum osculatum

Larvae of *C. osculatum* were extremely abundant in Newfoundland (30b, 4R-4Sv) cod but lacking in cod from southwestern Nova Scotia (4Wl, 4X-5ZEj) (Table 1; Figs. 5 and 8). These nematodes were usually found on mesenteries surrounding the pyloric caeca (95%) or elsewhere in the body cavity (5%).

Abundance of *C. osculatum* increased with host length (Fig. 11). A two-way ANOVA indicates that variations in parasite abundance related to host length and geographic origin of sample were highly significant, as was the interaction of host length and sampling effects (Table 5). While *C. osculatum* were quite numerous in both Whale Bank (30b) and northeastern Gulf (4R-4Sv) samples, the latter were more heavily infected ($P \leq 0.0001$) (Table 6). Larvae of *C. osculatum* were clearly far more abundant ($P \leq 0.0001$) in northeastern Gulf cod than in cod collected from the southern Gulf (4T) in 1980-81.

LARVAL ANISAKINES IN STRATIFIED FLATFISH SAMPLES

Pseudoterranova (Phocanema) decipiens

In the current survey, sealworms were most abundant in stratified samples of American plaice (*H. platessoides*) from the mouth of the Bay of Fundy (4Xrs) and the

northeastern Gulf of Maine (4Xq), and least abundant in plaice samples from the southwestern Grand Banks (30b) and Georges Bank (5ZEj) (Table 7). Sealworm densities in the fillets exceeded the government standard for maximum numbers permissible (0.73/kg) in all but the Grand Bank (30b) samples. Even in the latter samples, however, the standard was exceeded when *A. simplex* larvae (below) were included in the worm count.

Prevalence and abundance of sealworms in plaice generally increased with host length, but in many of the samples from southwestern Nova Scotia (4X-5ZEj), peak abundances occurred in fish 40 cm in length (Table 7; Fig. 13). The parasite occurred primarily (92%) in the fillets of Newfoundland (30b-4R) plaice and almost exclusively (298%) in the fillets of Nova Scotia plaice. Sealworm densities in the fillets, however, varied inversely to host length, the lowest densities being found in fish 25 cm in length (Table 7). Sealworm frequencies in the body cavity and napes, on the other hand, increased with host length (Table 8).

The two-way analysis of stratified plaice samples collected from areas 30 to 5ZEj reveals significant variation in sealworm abundance with geographic origin of sample and host length, and significant interaction between these sources of variation (Table 9). In some cases, however, contrasts proved insensitive to apparent differences in worm abundance (Table 10). While the mean sealworm counts in northeastern Gulf (4R) plaice were four to five times greater than those found in Whale Bank (30b) plaice, contrasts of samples from these areas were not significant ($P = 0.0692$ and $P = 0.0058$). Similarly, sealworms were far more numerous in plaice from the Brown's-LaHave-Roseway area (4Xo) than they were in George's Bank (5ZEj) plaice, but again, the contrast was not significant ($P = 0.0214$). Further contrasts indicate that sealworm abundance in 4R plaice did not differ from that in Magdalen Shoal (4T) plaice ($P = 0.1100$). Brown's-LaHave-Roseway plaice had significantly fewer ($P \leq 0.0001$) worms than plaice from adjacent areas such as Western Bank (4Wj), Sambro (4Xm) and the Jordan Basin (4Xq) (Table 10). Jordan Basin plaice, in turn, had fewer sealworms than plaice from Grand Manan Basin (4Xrs) ($P \leq 0.0001$).

Only two gray sole (*G. cynoglossus*) samples were collected during the current survey, one from the Baccaro-LaHave area (4Xno) and the other from Jordan Basin (4Xq) (Table 7). Sealworms were significantly more abundant ($P \leq 0.0001$) in the latter sample (Table 11). Sealworm abundance in Jordan Basin plaice was greater than that found in sole from Sable Island Bank (4Wf) in 1982, although perhaps not significantly so ($P = 0.0029$). Prevalence and abundance of sealworms increased with host length (Table 7),

variation with host length being highly significant (Table 11). The interaction between host length and sampling influences was also highly significant. Virtually all sealworm (299%) occurred in the fillets, and parasite density in the fillets was greatest in large fish.

A few sealworms were also found in the fillets of yellowtail flounder (*L. ferruginea*) from West Browns Bank (4Xp), but only the smaller (35 cm in length) fish were infected (Table 7). Variations in sealworm abundance in the Browns Bank sample and samples previously collected from 4T and 4VS-4W were not analyzed, as the four samples were widely separated geographically and only one length stratum (31 cm - 35 cm) was common to each sample.

Anisakis simplex

Newfoundland (30b and 4R) plaice were heavily infected with *A. simplex* larvae, the prevalence and abundance of the parasite increasing with host length (Table 7; Fig. 14). The nematodes were most frequently found in the body cavity, encysted on the liver (20%) and gastro-intestinal mesenteries (61%); 10% were detected in the napes and 2.3% in the fillets (Table 8). Parasite densities in the fillets were greatest in 46-cm to 50-cm plaice in the Whale Bank (30b) sample, while fillets from fish 251 cm in length had the greatest densities in the northeastern Gulf (4R) sample (Table 7).

Plaice from the Whale Bank (30b) and North Esquiman Channel (4Rab) did not differ significantly ($P=0.2417$) in respect to mean counts of *A. simplex* but the contrast of the worm-count/host-length interaction was highly significant ($P=0.0001$) (Table 10). While plaice from the south Esquiman Channel (4Rcd) had significantly fewer *A. simplex* than those from the northern part of the channel ($P\leq 0.0001$), they were, nevertheless, more heavily infected than Magdalen Shoal (4T) plaice ($P\leq 0.0001$).

A. simplex was not common in flatfishes from southwestern Nova Scotia. Prevalence in plaice ranged from <2% in the Georges Bank (5ZEj) sample to 6% in the Baccaro-LaHave (4Xo) sample. Only three *A. simplex* larvae were found in the fillets of 1,354 plaice from 4X-5ZEj, and the majority of larvae in the body cavity of Nova Scotia flatfish were non-anisakine species such as *Hysterothylacium* sp(p).

Contracaecum osculatum

Although numerous in Newfoundland (30b, 4R) plaice, *C. osculatum* larvae were not detected in flatfishes from southwestern Nova Scotia (4X-5ZEj) (Table 7). In Newfoundland plaice, the nematodes were usually encysted on the gastro-intestinal mesenteries (92.5%), particularly those of the stomach and pyloric caeca. A few (3%) were encysted on

the liver, while most of the remainder (4%) were encysted on other organs and mesenteries, or free in the body cavity. Three larvae (5% of the total) were found in napes, but the parasite was not detected in fillets.

Prevalence and abundance of *C. osculatum* in plaice increased with host length (Fig. 15) and variations in abundance with host length and sample were highly significant (Table 9). North Esquiman (4Rab) plaice had significantly greater numbers of *C. osculatum* than plaice from the southern portion of the channel (4Rcd) ($P\leq 0.0001$) (Table 10). While mean worm counts in south Esquiman and Magdalen Shoal (4T) plaice did not differ ($P=0.0204$), there was a significant difference ($P=0.0004$) in the worm-count/host-length interaction.

VARIATIONS IN ABUNDANCE OF SEALWORM IN THE FILLETS OF EASTERN CANADIAN PLAICE 31 CM-40 CM IN LENGTH (Tables 12 and 13; Figs. 16, 17 and 18)

Few sealworms were found in the fillets of plaice from Labrador and northeastern Newfoundland. Eleven worms were recovered from fish (n=319) collected near Hamilton Inlet Bank (2J) and a total of seven worms occurred in samples from Notre Dame Bay (3K) (n=200), Catalina Harbour (3L) (n=208) and the northern edge of the Grand Bank (3L) (n=277). The parasite was not detected in samples from offshore 3K and the eastern edge (3L-3N) and tail (3N) of the Grand Bank. Of 17 worms found in the Whale Bank (30) sample, 14 occurred in a single fish. According to T tests, mean worm counts in lightly infected 2J, 3K, 3L and 30 samples were not significantly greater than zero.

Significantly greater numbers of sealworms (Abundance = 0.30-0.40) were found in plaice from southern Newfoundland and St. Pierre Bank (3PS) ($P\leq 0.0001$). Sealworm abundance in the 3PS samples and in the majority of samples from the northern Gulf (4R-4S) and Magdalen Shoals (4T) varied from 0.13 to 0.49; contrasts of mean worm counts in this range were not significant. The parasite was more numerous (Abundance = 0.55-0.74) ($P\leq 0.0001$) in samples from Ferolle Point, Newfoundland, (4Ra) and the Miramichi area (4Tl), but the greatest sealworm abundances (1.13-1.71) in Gulf plaice were found in southeastern Gulf (4Tg) samples taken in the Cape George to Pleasant Bay, Nova Scotia area.

Scotia-Fundy plaice had the heaviest sealworm infestations overall. The parasite was uniformly abundant (Abundance = 1.57-2.13) in most samples from the Breton Shelf and eastern portion of the Scotian Shelf (4VS), although significantly fewer worms (Abundance = 0.68) ($P\leq 0.0001$) were found in the Misaine Bank sample and significantly greater numbers (Abundance = 2.87) ($P\leq 0.0001$) in the sample from West

Banquereau. Sealworms were most numerous (Abundance =3.92-6.58) in samples from the Sable Island area (4Wefj), northeastern Gulf of Maine (4Xq) and lower Bay of Fundy (4Xrs). Infections in plaice from Roseway Basin area (4Xo) were significantly lighter (Abundance 0.64-0.79) ($P \leq 0.0001$) and Georges Bank (5ZEj) plaice, in turn, had fewer sealworms (Abundance =0.29) than Roseway Basin fish ($P \leq 0.0001$).

COMPARISON OF GEOGRAPHICAL DISTRIBUTION OF SEALWORM IN COD AND PLAICE

Regressions of weighted mean worm counts on rank for 31-cm to 40-cm plaice and for cod in the 50, 51 to 70 and 271 cm length strata were in each case significant with a positive trend (Tables 14 and 15; Fig. 19). Regression coefficients for cod from 51 cm to 70 cm and 271 cm in length did not differ significantly from the regression coefficient for 31-cm to 40-cm plaice. As cod and plaice samples from corresponding locations were assigned the same rank (Fig. 20), the above analyses indicate that geographical variations in sealworm abundance in the two host species were similar.

DISCUSSION

DISTRIBUTION OF SEALWORM (*P. DECIPiens*) LARVAE IN EASTERN CANADIAN GROUND FISH

Surveys conducted three decades ago (Scott and Martin 1957; 1959; Templeman et al. 1957) indicated that sealworm (*P. decipiens*) were found in the fillets of various groundfish species throughout eastern Canada, but heavy infestations were limited to cod from the southern Gulf of St. Lawrence and inshore areas of southwestern Newfoundland, Nova Scotia and the Lower Bay of Fundy (Fig. 21). Evidently, this perception of sealworm distribution in eastern Canada persisted until the late seventies (Appy 1978; Odense 1978). Recent surveys (McClelland et al. 1983a and b) have revealed, however, that while sealworm infestations in the southwestern Gulf of St. Lawrence have remained stable, the parasite has become increasingly numerous in other areas. Infestations in cod and flatfish from the southeastern Gulf (4Tg), Breton Shelf (4VN) and eastern portion of the Scotian Shelf (4VS-4W) have reached abundances which, in many cases, greatly exceed those found in southwestern Gulf stocks. As shown in the present study (Tables 16 and 17), sealworm abundance has also increased in cod and American plaice from the southwestern Grand Banks (30), northern Gulf (4R-4S) and southwestern Scotian Shelf (4X), with worm abundance in samples from the latter two areas rivalling those found in southwestern Gulf cod and plaice.

It is possible that sealworm may have become more numerous in a number of other areas. In the current survey, a few sealworm were found in the fillets of plaice, 31cm - 40cm in length, from

Labrador (2J) and northeastern Newfoundland (3K-3L); whereas Templeman et al. (1957) reported that fillets of 31-cm to 40-cm plaice from areas 2J to 30 were worm free. The heavy worm infestations in cod in Passamaquoddy Bay (4Xs) are well documented (Scott and Martin 1957; Appy 1978), but our study reveals that offshore cod and flatfish from the mouth of Fundy (4Xrs) and northeastern Gulf of Maine (4Xq) are also heavily infected. Infections in cod and plaice from Georges Bank (5ZEj), reported herein, were light in comparison to those found off southwestern Nova Scotia; but processors, nevertheless, claim that sealworm is becoming a nuisance in Georges Bank cod.

Seals are of course the definitive hosts of *P. decipiens*. Among seal species in the North Atlantic, the gray seal (*Halichoerus grypus*) is the most important host, supporting on an individual and collective basis, the largest numbers of mature *P. decipiens* (McClelland et al. 1983a and 1983b). It is not surprising, then, that the growing extent and severity of sealworm infestations in eastern Canadian groundfish have paralleled the growth and redistribution of the gray seal population in the northwestern Atlantic. The area where worm infestations are most severe, i.e., the southeastern Gulf of St. Lawrence, and the Breton and Scotia shelves, encompasses the majority of known gray seal breeding and haulout areas. The gray seal population as a whole, and the two largest breeding populations in the southeastern Gulf and on Sable Island, have increased many fold during the last two decades (Mansfield and Beck 1977; Zwanenburg et al. 1981). Bounty and tag return programs (Zwanenburg 1984), as well as the comments of local fishermen, have indicated that gray seals are also quite numerous off southern Newfoundland, Labrador, and the north shore of the Gulf and Anticosti Island. Evidently, they now occur in large numbers off southwestern Nova Scotia and Grand Manan. The recent reappearance of gray seals in the latter two areas would explain apparent increases in sealworm abundance in offshore cod and flatfish on the southwestern Scotian Shelf and in the northeastern Gulf of Maine.

Over the past few decades gray seals have become increasingly numerous throughout the North Atlantic and Haukssoon (1984) attributes the growing prevalence and abundance of *P. decipiens* in Icelandic cod to this phenomenon. Smith and Wootten (1979), on the other hand, have found that sealworm abundances in Scottish and North Sea cod and whiting (*Merlangius merlangus*) have remained relatively stable in recent years in spite of the growth of local gray seal populations.

Although their role would be a secondary one, other seal species may have an impact on the worm problem in some areas. Worm infestations in some inshore fisheries, e.g., Passamaquoddy Bay, might be attributable in part or in whole to

local populations of harbour seals (*Phoca vitulina*). Individual harp seals carry few *P. decipiens* adults (Mansfield and Beck 1977), but the cumulative progeny of mature worms hosted by the large harp seal breeding populations in the Gulf of St. Lawrence could account for a significant portion of the worms occurring in 4T and 4R groundfish.

Migrations of fish or invertebrate host populations would also influence the geographical distribution of sealworm. This fact is best demonstrated in the southern Gulf of St. Lawrence (4T) where there are two plaice contingents, the southwestern or Magdalen Shoal group and the southeastern or Cape Breton group (Powles 1965). As shown here, sealworm burdens were far greater in the latter contingent, and hence sealworm is most abundant along Cape Breton and the north shore of mainland Nova Scotia, areas where ice-breeding gray seals occur. It is not possible to make the same distinction with Gulf cod which may occur in southwestern 4T in summer, southeastern 4T in fall and spring and on the Breton Shelf (4VN) in winter (Martin and Jean 1964; Kohler 1975). Much of the worm load in southwestern Gulf cod may have accumulated during seasonal migrations to the southeastern Gulf and Breton Shelf.

Other influences on sealworm distribution could include physical factors such as oceanic temperature, depth and currents (Templeman et al. 1957). Bottom temperatures on the Scotian Shelf may be optimal for embryonic development and hatching of sealworm eggs and subsequent larval development in poikilothermic hosts, while colder temperatures found in waters off Newfoundland and Labrador could retard hatching and larval development and perhaps prove lethal to the parasites (McClelland 1982).

Physical features on the Continental Shelf such as deep holes and channels may limit the movements of plaice and the benthic crustaceans which serve as precursor hosts of sealworm. Our data show that sealworm abundances were surprisingly uniform over large uninterrupted shallow areas, such as are found in the southwestern Gulf and on the Sable Island-Western-Middle Bank complex. There were great disparities in worm abundance, however, on the opposite sides of the Laurentian (separating 3P and 4V), Canso Bank, Misaine and Furdian channels. Currents, on the other hand, may act to disperse the eggs or invertebrate precursor hosts of sealworm. The accumulation of sealworm in groundfish in the southeastern Gulf of St. Lawrence, for example, might be attributable in part to the action of the Gaspé current which flows in a southeasterly direction from the St. Lawrence estuary, passing along the Northumberland and Cape Breton shores (Marine Research Associates Ltd. 1980).

An instantaneous picture of larval sealworm distribution in eastern Canada was provided by our survey of American plaice. In this survey, sampling was limited to fish in the 31-cm to 40-cm length range and only the fillets were examined for parasites. This approach to monitoring sealworm abundance and distribution offered many advantages over surveys employing cod as the indicator host (McClelland et al. 1983b). Because of the small size of plaice chosen, the samples were easier to transport, required far less storage space and could be examined more quickly than cod samples. By limiting sampling to a single length stratum, there was no need to consider variations related to host length or interaction effects in subsequent analyses of worm abundances. One-way analyses (of variations related to sample or geographical origin) permitted adjustments for heterogeneity of variance which were not possible in two-way analyses. In two-way analyses, herein and in earlier reports (McClelland et al. 1983a and 1983b), the assumption of homogeneity of variance was ignored.

Regression analyses indicate that geographical trends in sealworm distribution in plaice and cod were similar (Table 15, Fig. 19). As plaice are more sedentary than cod, however, worm abundances in plaice samples may be more indicative of true sealworm abundances in discrete geographical areas. Our plaice survey, for example, revealed a significant disparity in sealworm abundances in the southwestern and southeastern Gulf of St. Lawrence (discussed above), a disparity which was not apparent in surveys of migratory 4T cod stocks.

An analysis of sealworm abundances in 31-cm to 40-cm plaice indicates that many of our samples were superfluous. The parasite was either lacking or occurred in insignificant numbers in samples from Labrador, northeastern Newfoundland and the Grand Banks. Sealworm abundances did not vary significantly in samples from southern Newfoundland or in the majority of samples from the northern and southwestern Gulf of St. Lawrence. The parasite was also uniformly abundant in samples from the Breton Shelf and adjacent areas of the Scotian Shelf. Hence, sealworm distribution could be monitored just as effectively with a reduced number of sampling stations in the areas above. Twenty-five to thirty sampling stations may be more than adequate in future surveys (Fig. 22), however, the sample size employed in the current survey ($n=150\pm50$) would be retained.

Given the volatility of the sealworm problem in recent years, the abundance and distribution of the parasite should be monitored at frequent intervals. Our surveys show that worm abundances in plaice from the Miramichi area, Breton Shelf, Banquereau, Sable Island and Western Banks have increased significantly within the

past three years (Table 18). In a sample taken from the eastern shoal of Banquereau in 1983, sealworm was twice as prevalent and four times more abundant than it was in a sample from the same location one year earlier. By using a scaled-down version of the plaice survey employed herein, sealworm distribution could be monitored every two or three years with minimal labour or expense. Most of the samples could be collected during DFO groundfish cruises.

DISTRIBUTION OF A. SIMPLEX IN EASTERN CANADA

In our recent surveys of eastern Canadian cod and plaice, A. simplex was clearly most numerous in fish from Newfoundland waters and least numerous in lower Bay of Fundy and Georges Bank fish. This apparent trend towards greater abundance of this parasite in teleosts from the northerly latitudes is consistent with that observed by European investigators (Davey 1971; Platt 1975; Wootten and Smith 1976; Smith and Wootten 1978; Smith 1983a, 1983b and 1984). Cosmopolitan in distribution, A. simplex is most common in colder temperate and polar waters of the northern hemisphere. Densities of A. simplex in the flesh (fillets and nape included) of Newfoundland cod herein were similar to those reported in British and Icelandic cod, but not nearly as great as those found in North Sea and Arcto-Norwegian cod (Young 1972; Platt 1975; Wootten and Waddell 1977; Smith and Wootten 1979; Hauksson 1984). On the other hand, the heavy A. simplex infestations in Newfoundland groundfish may be a recent development (see Tables 16 and 17). In the present study, A. simplex densities in fillets (no./kg) were 0.23 in Whale Bank (30) cod and 0.82 in northeastern Gulf (4R-4Sv) cod. The parasite was also found in the fillets of plaice from Hamilton Inlet Bank (2J) (density = 0.26), eastern Newfoundland (3L) (dens. = 0.29), Whale Bank (30) (dens. = 0.88), southern Newfoundland (3PS) (dens. = 0.56) and the northeastern Gulf (4R) (dens. = 0.57). According to earlier records of Templeman et al. (1957), however, densities of Anisakis larvae in the fillets of 30 and 4R-4S cod were 0.03 and 0.05, respectively; Anisakis larvae were not detected in the fillets of 2J, 3L, 30, 3PS or 4R plaice. Smith and Wootten (1979) have observed similar increases in abundance of Anisakis larvae in the flesh of cod and whiting (Merlangius merlangus) from the north coast of Scotland over a relatively short period of time; comparison of data from 1971-73 and 1978-79 surveys revealed that Anisakis abundances in cod flesh were four to sixteen times greater in the latter survey.

The disparity in abundance of A. simplex in Newfoundland and Nova Scotia fisheries may not have existed as recently as 15 years ago. A survey by Parsons and Hodder (1971) indicated that the heaviest

Anisakis infestations in Newfoundland herring (Clupea harengus) occurred in fish from the northwest coast (4R) and southern Labrador (2J) but the parasite was equally abundant in Banquereau (4VS), Chedabucto Bay (4W) and St. Mary's Bay (4X) herring. In a more recent survey (McGladdery 1984), abundances of A. simplex larvae in herring from the south (3PS) and west (4R) coasts of Newfoundland were considerably greater than those reported by Parsons and Hodder.

The factors which influence the geographical distribution of A. simplex are poorly understood (Smith and Wootten 1978). Like sealworm, A. simplex matures and reproduces in the gastro-intestinal tract of marine mammals, and 26 cetacean and 12 pinniped species have been listed as definitive hosts (Davey 1971; Dailey and Brownell 1972). Unfortunately, there have been few quantitative studies of the parasite in its marine mammal hosts and our knowledge of the distribution and abundance of the hosts themselves is inadequate. Vladykov (1944) reports that beluga whales (Delphinapterus leucas) in the St. Lawrence estuary are heavily infected with A. simplex, "as much as a gallon" of worms being found in a single stomach. Scott and Fisher (1958a) found approximately 400 Anisakis in the stomach of beluga collected in the Bay of Fundy and noted that 50% of the parasites were sexually mature. According to Scott and Fisher, however, common porpoises (Phocoena phocoena) in the Bay of Fundy were lightly infected, the mean numbers of nematodes (incl. Anisakis and Pseudoterranova) recovered ranging from 2 to 13. Each of five white-beaked dolphins (Lagenorhynchus albirostris) beached in Conception Bay, Nfld., was infected with Anisakis (Sergeant and Fisher 1957); and Sergeant (1962) reports that A. simplex is commonly found in long-finned pilot whales (Globicephala melaena) in Newfoundland waters. In a survey of cetaceans in the northeast Atlantic, Young (1972) reports A. simplex in common porpoises, sperm (Physeter catodon), long-finned pilot, minke (Balaenoptera acutorostrata) and fin (Balaenoptera physalis) whales. Evidently, pinnipeds play a relatively minor role in the life cycle of A. simplex in the North Atlantic. Although larvae of the parasite frequently occur in European and eastern Canadian gray seals, for example, few develop to maturity in this host (Young 1972; Smith and Wootten 1978; McClelland 1980b and 1980c).

It is highly unlikely that cetacean populations, even those protected prior to the 1972 moratorium on whaling, have recovered sufficiently to have influenced increases in A. simplex abundance of the magnitude found in Newfoundland and Scottish fisheries. The long-finned pilot or pothead whale population in eastern

Newfoundland may have made a significant recovery since the sixties (Hay 1982). However, Hay's current estimate of pothead abundance (13,000 $\pm$ 3,000) is well below the estimate for 1947 (50,000-60,000) (Mercer 1975) at the onset of exploitation. Hay speculates that Newfoundland-Labrador and Nova Scotian fin whale stocks responded differently to exploitation, the decline in the former stock having been less dramatic than that in the latter. Humpback whales (*Megaptera novaeangliae*) have been protected since 1962, and recent estimates indicate that the population may have grown significantly (Katona et al. 1983). Hay (1982) points out, however, that because of differences in field sampling and analytical procedures, recent and earlier estimates of the humpback population may not be strictly comparable. Given the lack of recent and/or earlier population estimates, it is not possible to comment on trends in abundances of blue (*Balaenoptera musculus*), sei (*B. borealis*) and minke whales, and small odontocetes such as the white-beaked and white-sided (*Lagenorhynchus acutus*) dolphins in Newfoundland waters.

Many important prey species of cetaceans are intermediate or paratenic hosts of *A. simplex*. Smith (1983a) found *A. simplex* in five species of northeastern Atlantic and North Sea krill (Euphausiidae: *Thysanoessa inermis*, *T. raschii*, *T. longicauda*, *Nyctiphanes couchii* and *Meganctiphanes norvegica*) and noted that prevalence of infection in these crustaceans was highest in areas where the parasite was particularly abundant in fish. Krill are important prey not only for baleen whales, definitive hosts of *A. simplex*, but also for other intermediate hosts of the parasite including pelagic fish such as herring and mackerel (*Scomber scombrus*) (Smith 1983b) and cephalopod molluscs (Squires 1957). The overall prevalence of *A. simplex* in krill is very low (Smith 1983a) but certain fish species may consume these crustaceans in sufficient quantities to incur heavy *A. simplex* infestations. If krill is a key participant in the life cycle of *A. simplex*, as Smith (1983b) suggests, it is difficult to explain the low abundance of the parasite in our cod and plaice samples from the lower Bay of Fundy. Huge swarms of krill occur in the mouth of the Bay of Fundy in late summer and these are preyed upon by large schools of herring and mackerel, and numerous whales (Gaskin 1982). To our knowledge, however, no one has surveyed nematode parasites of eastern Canadian krill and it is possible that the species found in the Bay of Fundy, mainly *Meganctiphanes* sp. (Gaskin 1982), are not suitable hosts for *A. simplex*. It is also possible that krill become infected by consuming smaller "transfer" hosts such as copepods (Smith 1983b) and *A. simplex* may be specific for copepod and/or krill species common to more northerly latitudes.

In his most recent study, Smith (1984) reports abundances of *A. simplex* larvae in North Sea squid. While offshore oegopsid squid (*Todarodes sagittatus* and *Todaropsis eblanae*) were heavily infected (prevalence = 62%, abundance = 3.8 [1-46] for *T. sagittatus*), the parasite did not occur frequently in inshore myopsid squid (*Loligo forbesi* and *Alloteuthis media*) from the north Scotland inshore (prevalence = 6% in *L. forbesi* and 0.1% in *A. media*). The short-finned squid (*Illex illecebrosus*) in Newfoundland waters, on the other hand, seems to accumulate *A. simplex* during seasonal migrations inshore. Squires (1957) found that the prevalence of larval nematodes in short-finned squid was generally low (1.3%), but the parasite was somewhat more prevalent (6.1%) in larger inshore squid which had been feeding on small fish such as capelin; smaller squid found offshore fed mainly on euphausiids. In a more recent study, Threlfall (1982) found only 12 *Anisakis* larvae in 2,300 squid collected on their arrival in inshore areas of eastern Newfoundland in early June to mid-August, but found 100 nematodes in 230 squid collected later in the season, between mid-September and mid-October.

The short-finned squid is the primary prey of long-finned pilot or pothead whales in Newfoundland waters (Sergeant 1962). According to Sergeant, *A. simplex* first appeared in the stomachs of young potheads at the time the first squid remains were found, indicating that the squid was the precursor host. The availability of potheads in the Newfoundland inshore seems closely related to cyclical variations in abundance of squid (Mercer 1975). As both the whale and the squid seem to accumulate *A. simplex* inshore (Sergeant 1962; Threlfall 1982), overall abundances of the parasite may also vary with cyclical changes in squid abundance and/or distribution. The heavy *A. simplex* infestations currently being experienced in Newfoundland fisheries may then be a manifestation of the most recent peak in squid abundance in the late seventies.

Teleosts are preyed upon by odontocetes and many baleen whales in the north Atlantic (Gaskin 1982). Many of the species consumed, such as herring, salmon and cod, are at times heavily infected with *A. simplex* larvae (Parsons and Hodder 1971; Beverley-Burton et al. 1977; herein). In Newfoundland waters, however, capelin appears to be an important prey species, comprising the greater part of the diet of fin, humpback and minke whales in late spring and summer (Sergeant 1963 and 1966; Mitchell and Kozicki 1975). Palsson and Beverley-Burton (1984) describe *A. simplex* in capelin from Trinity Bay (3L), and the parasite was frequently found in capelin collected from the Trepassey area (3L) in the present study. While *A. simplex* abundances in capelin are relatively low (Palsson 1982), whales would consume these fish in sufficient quantities to accumulate large numbers of the parasite.

As the predominant prey species for cod in Newfoundland waters and the Northern Gulf of St. Lawrence (Minet and Perodou 1978; Winters and Carscadden 1978), capelin is also a probable source of A. simplex infections in cod from these areas. Larger cod (275 cm in length) from the northern Gulf, on the other hand, may accumulate the parasite by feeding on herring - a prey species which becomes increasingly prevalent in the diet of mature 4R-4S cod (Minet and Perodou 1978).

Although there are no prior records of Anisakis larvae in eastern Canadian sand lance (Ammodytes spp.) (Margolis and Arthur 1979), our studies indicate that this species may also be an important intermediate host of A. simplex. Cod and plaice collected from the Whale Bank (30) in June '83 were feeding primarily on sand lance (A. dubius). Cursory examinations of the viscera of 30 sand lance from Whale Bank (30) revealed that each was infected with A. simplex (i.e., prevalence = 100%). Sand lance are important prey for Grand Bank cod and plaice (Winters 1983).

DISTRIBUTION OF C. OSCULATUM IN EASTERN CANADA

At least 22 species of pinniped have been identified as definitive hosts of C. osculatum; these hosts include otariids and phocids, found throughout the northern and southern hemispheres, and the Atlantic and Pacific oceans (Dailey and Brownell 1972). The parasite has even been found in the rare Mediterranean monk seal (Monachus monachus) and in the landlocked seals (Pusa sibirica) of Lake Baikal in the U.S.S.R. The life cycle of C. osculatum is probably similar to that of the sealworm (McClelland 1980a, b and c; 1982; McClelland et al. 1983a), but the intermediate hosts of the parasite remain largely unknown. The difficulty of making a positive identification of C. osculatum larvae in marine invertebrates or teleosts lies in the likelihood of confusing it with the larvae of other nematode species (Contracaecum, Phocascaris and Hysterothylacium spp.) which are morphologically similar and often parasitize the same hosts (Berland 1963; Wootton 1978).

Sudarikov and Ryzhikov (1951) identified Contracaecum larvae from the viscera of yellowfin sculpin (Cottocomephorus greswinki) of Lake Baikal as C. osculatum on the basis of morphological similarities to nematodes in Baikal seals. Wootton (1978) concluded that larval Contracaecum from small gadoids (cod and related species) in North Sea waters were probably C. osculatum in view of the great abundance of this species in the local gray seal population. A similar rationale was employed in our tentative identification of C. osculatum larvae in cod and plaice from the southern Gulf of St. Lawrence (McClelland et al. 1983a), but in this case, harp seals breeding near the Magdalen Islands were cited as the probable

source of infection. In their description of Contracaecum larvae in Newfoundland capelin, Palsson and Beverley-Burton (1984) also imply that the nematodes might be C. osculatum, given their abundance in eastern Canadian harp seals. Prior to the present study, however, only Fagerholm (1982) has made a positive identification of C. osculatum in a fish host. In Fagerholm's study, larval nematodes from the viscera of Baltic cod were identified as C. osculatum following surgical implantation and maturation in the peritoneal cavities of laboratory rats.

Capelin may be the most important intermediate host of C. osculatum in Newfoundland-Labrador and Gulf fisheries. Harp seals, the principal definitive host of C. osculatum in eastern Canada (Myers 1957; Scott and Fisher 1958b; Mansfield and Beck 1977; McClelland 1980b and 1980c) feed primarily on capelin (Sergeant 1973) and capelin is the predominant prey of cod in Newfoundland-Labrador and northern Gulf waters (Minet and Perodou 1978; Winters and Carscadden 1978). The heavy C. osculatum infestations which we observe in northern Gulf and Grand Bank cod may very well result from consumption of capelin.

In an early survey of larval nematodes in the body cavities of capelin from Newfoundland and Labrador, Templeman (1948) found that the prevalence of infection was 58% overall, varying from 0% to 85%, while abundance of parasites was 1.07 varying from 0 to 1.83. Prevalence and abundance generally increased with host length, and the heaviest infections occurred in fish from the northeastern and eastern coasts of Newfoundland. At the time, these parasites were identified as Contracaecum clavatum, a synonym of Hysterothylacium aduncum. A subsequent survey of Grand Bank capelin (Winters and Campbell 1974) revealed somewhat lower levels of nematode infection (prevalance = 10%-40%; abundance = 0.10-0.40). The most recent study (Palsson and Beverley-Burton 1984), however, shows that the larvae of three species of ascaridoid, Anisakis simplex, Contracaecum sp. and Hysterothylacium sp., occur in the body cavities of Newfoundland capelin; Contracaecum sp., with prevalences as high as 78%, was the most common of the three (Palsson 1982). These same three species of nematode were found in capelin from Trepassey, Newfoundland, in the present study. Most of the specimens recovered (280%) were C. osculatum larvae, their identity being verified by morphometric comparisons with nematodes from cod and C. osculatum larvae reared in vitro (McClelland and Ronald 1974b).

The heavy C. osculatum infections in our cod and plaice samples from the southwestern Grand Banks were rather surprising, as this area lies some distance from major concentrations of harp seals in the Gulf, and off southern Labrador and northeastern Newfoundland. However, the inshore branch of the Labrador current flows through Labrador and northeastern

Newfoundland waters to the southwestern Grand Banks and southern Newfoundland (Marine Research Associates Ltd. 1980). Possibly, the eggs and/or invertebrate precursor hosts of *C. osculatum* are carried along with this current.

As *C. osculatum* larvae rarely occur in the flesh of fish, they are of little consequence as a possible human pathogen or as a cosmetic problem for fish processors. On the contrary, this parasite may have a beneficial impact on North Atlantic fisheries by interfering with the proliferation of sealworm (*P. decipiens*).

Berland (1963) observed that *C. osculatum* seemed to compete with and displace other species of anisakine nematode from the stomachs of harp and hooded (*Cystophora cristata*) seals. *C. osculatum* overwhelmingly outnumbers *P. decipiens* in harp seals in the Gulf of St. Lawrence (Myers 1957; Scott and Fisher 1958b; Mansfield and Beck 1977) and is also considerably more abundant than *P. decipiens* in British gray seals (Young 1972). It is perhaps no coincidence, then, that sealworm abundances in Gulf (McClelland et al. 1983a; herein) and British groundfish (Smith and Wootten 1979) have remained relatively stable in spite of the growth of the gray seal populations in these areas. In Scotian Shelf fisheries, where *C. osculatum* is seldom found, there have been phenomenal increases in sealworm abundance in the past few years (McClelland et al. 1983b; herein).

Modest increases in sealworm abundance were detected in cod and plaice from some areas of the Gulf of St. Lawrence and Newfoundland in the present study. But gray seals move freely from the Sable Island-Scotian Shelf area to the Gulf and southern Newfoundland (Zwanenburg 1984) and recent migrants from the Shelf would, presumably, be heavily infected with *P. decipiens*. The impact of migrant gray seals on sealworm abundances in Gulf or Newfoundland fisheries would be a temporary one, dissipating as the *P. decipiens* carried by these seals are replaced by *C. osculatum*. At present, this discussion is highly speculative but of possible relevance are data on worm abundances in gray seals in the Northumberland Strait area (from McClelland 1980b and 1980c). Nine adult seals collected at the time of their first arrival on Amet Island, in early fall, were infected mainly (290% of nematodes present) with *P. decipiens*; abundance of this parasite was 710 (109-1,653) including 196 (8-480) mature female worms. In five adult seals subsequently collected from this colony in winter, however, abundance of *P. decipiens* had fallen to 199 (33-574) and there were no mature females. Over this same period, the proportion of *C. osculatum* among nematodes in the stomachs had increased from 2% to 55%.

DISTRIBUTION OF LARVAL ANISAKINES IN THE TISSUES OF FISH HOSTS

While *A. simplex* infestations were mainly confined to the visceral mesenteries of fish hosts, the proportions of *Anisakis* larvae in the flesh of our Newfoundland cod and plaice samples were somewhat higher than those found in other areas surveyed. Over 9% of *A. simplex* in Newfoundland cod and 212% of *A. simplex* in Newfoundland plaice were found in the flesh. In southern Gulf, Scotian Shelf and southwestern Nova Scotia samples, on the other hand, 53% of the *A. simplex* occurred in the flesh (McClelland et al. 1983a and 1983b; herein). Given the difficulties of locating *Anisakis* larvae by candling, slicing or destructive examinations of the flesh, however, tallies of this nematode in fillets and napes may not be particularly accurate. Experiments in which the fillets and napes of cod were subjected to a pepsin digest, following routine inspections for parasites (McClelland et al. 1983a), indicated that approximately two-thirds of the *Anisakis* larvae escaped detection by destructive examination of the flesh; with the nematodes recovered by the digestion procedure, the frequency of *Anisakis* larvae in the flesh of Scotian Bank (4VN) cod exceeded 20%. British investigators (Wootten and Waddell 1977), using candling and slicing techniques, found that approximately 12% of *A. simplex* in Scottish and North Sea cod occurred in the flesh, but in whiting (*Merlangius merlangus*), a much smaller host, the parasite was more numerous in the flesh than it was in the viscera.

In the present study, >80% of the *Anisakis* larvae in the flesh of cod and plaice were located in the napes (the hypaxial musculature of the abdomen). This seems to be consistent with British records (Young 1972; Wootten and Waddell 1977; Wootten 1978) which show that from 85% to 100% of *A. simplex* in the flesh of cod and other fish hosts occur in the hypaxial musculature. In our earlier surveys (McClelland et al. 1983a and 1983b), however, the few *A. simplex* which were found in the flesh of 4T, 4VN and 4VS-4W cod, seemed to be evenly distributed between napes and fillets.

Our studies show that the fillets are the primary site of sealworm (*P. decipiens*) infection in cod and other fish species of eastern Canada. Frequencies of occurrence in the napes and body cavity increased with the size of the host, but in no case was the frequency in the fillets less than 68%. British investigators (Young 1972; Platt 1975; Wootten and Waddell 1977) have also remarked on a decrease in the proportion of sealworm in the fillets (epaxial musculature) of older cod, but in British cod (22 years of age) the parasite becomes more numerous in the napes (hypaxial musculature) than in the fillets.

Further analyses, herein, of nematodes in the flesh of cod revealed that sealworm and *A. simplex* larvae were more numerous in the left side (nape and fillet) of the body; the ratio of nematode abundances in the left side to those in the right was 1.5:1 (1.2:1 to 2.7:1) and the disparity in abundance of *A. simplex* in left and right sides was highly significant. Evidently, the cod liver which lies, for the most part, dorsally and to the right of the gut, may interfere with migrations of larval nematodes from the gut to the hypaxial (or epaxial) musculature on the right side of the body. Indeed, the majority of *A. simplex* larvae in cod tend to accumulate on the liver. Arthur et al. (1982) studied distributions of *P. decipiens* and *A. simplex* in the musculature of walleye pollock (*Theragra chalcogramma*) from British Columbia, but in this case found no significant differences in the abundances of nematodes in the left and right side of the body.

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TABLE.1 Prevalence and abundance of larval anisakines in round cod from Whale Bank (30b), the northeastern Gulf of St. Lawrence (4R-4Sv) and southwestern Nova Scotia (4W1, 4X and 5ZEj).

Host			Larval anisakines detected							
Sample a	Location and date	Length range (cm)	n	<u>P. decipiens</u>			<u>A. simplex</u>		<u>C. osculatum</u>	
				Prevalence	Abundance	Density in fillets ^b	Prevalence	Abundance	Prevalence	Abundance
33	Whale Bank (30b) May 84	≤40	30	7	0.07	0.47	57	1.93	0	0
		41-45	29	3	0.10	0.49	62	1.97	17	0.28
		46-50	25	0	0	0	84	2.68	56	1.32
		51-55	25	12	0.16	0.44	92	6.52	72	4.00
		56-60	23	17	0.30	0.45	100	9.30	70	5.78
		61-65	31	13	0.13	0.22	100	10.32	74	10.42
		66-70	19	11	0.16	0.21	100	19.26	84	13.89
		≥71	24	42	1.42	0.58	100	36.17	75	7.42
		Total	206	13	0.28	0.40	85	10.26	53	5.04
32	Esquimaux Channel (4R-4Sv) Jan 84	≤40	43	7	0.09	0.53	70	3.42	23	0.33
		41-45	22	14	0.23	0.85	95	5.68	50	1.55
		46-50	41	20	0.29	0.83	98	11.27	63	2.39
		51-55	58	33	0.45	0.91	100	18.52	76	3.74
		56-60	28	36	0.82	1.16	100	19.96	89	7.36
		61-65	19	47	1.53	1.82	100	31.79	95	15.95
		66-70	6	50	0.67	0.40	100	28.33	100	19.17
		≥71	5	100	8.80	4.20	100	68.40	100	30.60
		Total	222	27	0.66	1.29	93	15.69	65	5.14
30	Emerald Bank (4W1) Oct 83	≤50	13	62	1.08	3.95	46	1.15		
		51-55	13	54	0.85	2.01	31	0.77		
		56-60	19	74	2.42	4.39	79	2.11		
		61-65	15	87	6.53	8.63	100	10.07		
		66-70	22	86	5.00	5.26	95	9.77		
		≥71	33	94	10.61	6.87	100	14.61		
		Total	115	76	4.42	5.19	75	6.41		
28	Roseway Bank (4Xo) Jul 83	≤40	36	19	0.31	2.04	25	0.33		
		41-45	54	22	0.38	1.60	28	0.52		
		46-50	59	49	0.95	2.94	32	0.71		
		51-55	40	70	1.18	2.67	68	2.18		
		56-60	34	68	1.71	3.00	62	1.65		
		61-65	28	75	2.64	3.57	75	3.07		
		66-70	15	67	2.00	2.18	80	2.80		
		≥71	16	88	11.00	6.45	88	6.81		
		Total	282	51	1.68	3.38	49	1.64		

TABLE 1 (continued)

Host			Larval anisakines detected							
			<u>P. decipiens</u>				<u>A. simplex</u>		<u>C. osculatum</u>	
Sample a	Location	Length range			Density in					
No.	and date	(cm)	n	Prevalence	Abundance	fillets	Prevalence	Abundance	Prevalence	Abundance
29	East Browns Bank (4Xp) Aug 83	≤40	11	18	0.55	3.21	9	0.04		
		41-45	27	48	0.85	3.55	26	0.26		
		46-50	44	25	0.36	1.10	50	0.66		
		51-55	51	49	0.63	1.46	39	0.49		
		56-60	41	51	1.05	1.91	44	0.63		
		61-65	27	70	1.52	2.09	44	0.85		
		66-70	14	86	2.21	1.96	86	1.64		
		≥71	22	82	11.18	4.58	95	3.68		
	Total	237	51	1.85	2.66	48	0.91			
31	Lower Bay of Fundy (4Xrs) Mar 83	≤40	28	32	0.71	6.57	4	0.04		
		41-50	14	64	2.64	7.96	14	0.14		
		51-55	32	75	2.72	5.34	3	0.03		
		56-60	32	78	4.59	7.09	16	0.25		
		61-65	35	89	4.06	4.62	17	0.20		
		66-70	21	90	4.38	4.17	29	0.33		
		≥71	28	82	8.39	3.77	43	1.71		
			Total	190	74	4.00	4.81	17	0.39	
26	Fundian Channel (5ZEj) Jun 83	≤40	13	0	0	0	0	0		
		41-45	28	7	0.07	0.31	4	0.04		
		46-50	32	28	0.50	1.58	9	0.13		
		51-55	38	26	0.29	0.65	8	0.08		
		56-60	23	17	0.74	1.27	13	0.22		
		61-65	37	22	0.46	0.56	24	0.32		
		66-70	21	19	0.57	0.58	24	0.38		
		≥71	27	41	0.93	0.50	52	1.81		
	Total	219	22	0.46	0.62	17	0.37			
27	Georges Bank (5ZEj) Jun 83	≤40	6	0	0	0	17	0.17		
		41-45	19	32	0.84	3.33	11	0.16		
		46-50	23	22	1.09	3.10	17	0.17		
		51-55	17	24	0.59	1.25	6	0.06		
		56-60	21	10	0.19	0.35	19	0.19		
		61-65	24	25	0.33	0.46	17	0.17		
		66-70	21	43	0.86	0.83	38	1.10		
		≥71	17	59	4.19	2.43	65	2.47		
	Total	148	28	1.04	1.49	23	0.55			

a. Refer to Fig. 1.

b. Number of nematodes per kg fillet.

TABLE.2 Distribution of larval anisakines in the tissues of cod from Whale Bank (30b), the northeastern Gulf (4R-4Sv) and southwestern Nova Scotia (4W1, 4X and 5ZEj).

Host		Larval anisakines		Distribution in host tissues (%)		
Locations	Length range(cm)	Species	n	Body cavity	Napes	Fillets
30b, 4R-4Sv	≤50	<u>P. decipiens</u>	26	3.85	11.54	84.62
		<u>A. simplex</u>	916	86.24	11.24	2.51
	51-70	<u>P. decipiens</u>	100	9.00	9.00	82.00
		<u>A. simplex</u>	3,950	89.72	8.61	1.67
	≥71	<u>P. decipiens</u>	78	21.79	10.26	67.95
		<u>A. simplex</u>	1,210	96.53	2.89	0.58
	Total	<u>P. decipiens</u>	204	13.25	9.80	76.96
		<u>A. simplex</u>	6,076	90.55	7.87	1.58
	≤50	<u>P. decipiens</u>	263	1.52	2.66	95.06
		<u>A. simplex</u>	150	95.33	2.00	2.67
4W1, 4X and 5ZEj	51-70	<u>P. decipiens</u>	1,186	1.10	8.85	90.05
		<u>A. simplex</u>	869	98.50	1.38	0.12
	≥71	<u>P. decipiens</u>	1,105	4.71	14.57	80.72
		<u>A. simplex</u>	811	99.26	0.74	0
	Total	<u>P. decipiens</u>	2,554	2.70	10.69	86.61
		<u>A. simplex</u>	1,830	98.58	1.15	0.27

TABLE.3 Distribution of larval anisakines in the flesh of 30b, 4R-4Sv, 4W1, 4X and 5ZEJ cod.

Host		Larval anisakines		Distribution in host tissues (%)						
Locations	Length range(cm)	Species	n	Left side			Right side			No. in left side + No. in right side
				Nape	Fillet	Total	Nape	Fillet	Total	
30b, 4R-4Sv	≤50	<u>P. decipiens</u>	25	8.00	52.00	60.00	4.00	36.00	40.00	1.50
		<u>A. simplex</u>	126	51.59	13.49	65.08	30.16	4.76	34.92	1.86
	51-70	<u>P. decipiens</u>	91	8.79	52.75	61.54	1.10	37.36	38.46	1.60
		<u>A. simplex</u>	406	52.71	10.34	63.05	31.03	5.91	36.95	1.71
	≥71	<u>P. decipiens</u>	61	8.20	55.74	63.93	4.92	31.15	36.07	1.77
		<u>A. simplex</u>	41	63.41	9.76	73.17	21.95	4.88	26.83	2.73
Total		<u>P. decipiens</u>	177	8.47	53.67	62.15	2.82	35.03	37.85	1.64
		<u>A. simplex</u>	573	53.23	10.99	64.22	30.19	5.58	35.78	1.80
4W1, 4X	≤50	<u>P. decipiens</u>	130	3.08	52.31	55.38	0.77	43.85	44.62	1.24
and	51-70	<u>P. decipiens</u>	924	5.19	49.46	54.65	4.65	40.69	45.35	1.21
5ZEJ a	≥71	<u>P. decipiens</u>	816	10.05	51.96	62.01	5.76	32.23	37.99	1.63
Total		<u>P. decipiens</u>	1,870	7.17	50.75	57.91	4.87	37.22	42.09	1.38

a. Includes data from Emerald Bank, Browns Bank, Grand Manan Basin and Fundian Channel samples.

TABLE.4 Three-way Type-III ANOVAs for variations in abundance of larval anisakines in the flesh (nape and fillet) of cod^a with host length, sample and side.

Source of variation	Nematode species	Degrees of freedom	Type-III mean square	F	P > F
<u>Main effects</u>					
Host length	<u>P. decipiens</u>	2	5.934	82.27	≤0.0001
	<u>A. simplex</u>	2	0.488	26.58	≤0.0001
Host sample	<u>P. decipiens</u>	5	3.703	51.28	≤0.0001
	<u>A. simplex</u>	5	1.379	75.09	≤0.0001
Host side	<u>P. decipiens</u>	1	0.465	6.45	0.025
	<u>A. simplex</u>	1	0.283	15.42	≤0.0001
<u>Two-way interactions</u>					
Length X sample	<u>P. decipiens</u>	10	0.558	7.73	≤0.0001
	<u>A. simplex</u>	10	0.332	18.06	≤0.0001
Length X side	<u>P. decipiens</u>	2	0.164	2.28	ns
	<u>A. simplex</u>	2	0.034	1.85	ns
Sample X side	<u>P. decipiens</u>	5	0.006	0.09	ns
	<u>A. simplex</u>	5	0.083	4.53	0.001
<u>Three-way interaction</u>					
Length X sample X side	<u>P. decipiens</u>	10	0.014	0.20	ns
	<u>A. simplex</u>	10	0.016	0.87	ns
<u>Error</u>	<u>P. decipiens</u>	1,170	0.072 ^b		
	<u>A. simplex</u>	1,170	0.018 ^b		

a. Analysis of Whale Bank(30b), northern Gulf (4R-4Sv), Emerald Bank (4W1), Browns Bank (4Xp), Grand Manan Basin (4Xrs) and Fundian Channel (5ZEj) samples.

b. For pooled fish.

TABLE.5 Two-way Type-III ANOVAs for variations in abundance of larval anisakines with sample and length of eastern Canadian cod^a.

Source of variation	Nematode species	Degree of freedom	Type-III mean square	F	P&F
<u>Main Effects</u>					
Sample	<u>P. decipiens</u>	30	5.977	61.16	<0.0001
	<u>A. simplex</u>	30	8.059	105.49	<0.0001
	<u>C. osculatum</u>	30	3.635	113.99	<0.0001
Host length	<u>P. decipiens</u>	5	18.051	184.71	<0.0001
	<u>A. simplex</u>	5	10.375	135.82	<0.0001
	<u>C. osculatum</u>	5	1.883	59.03	<0.0001
<u>Interaction</u>					
Sample X host length	<u>P. decipiens</u>	150	0.443	4.53	<0.0001
	<u>A. simplex</u>	150	0.436	5.70	<0.0001
	<u>C. osculatum</u>	150	0.397	12.44	<0.0001
<u>Error</u>	<u>P. decipiens</u>	7,471	0.098		
	<u>A. simplex</u>	7,471	0.076		
	<u>C. osculatum</u>	7,471	0.032		

a. Includes data from McClelland et al. (1983a and b).

TABLE.6 Two-way contrasts of abundances of larval anisakines in stratified samples of eastern Canadian cod.

a Contrast		Nematode species	Sample		Sample X host length	
			F	PzF	F	PzF
Whale Bank (30b)	vs. Esquiman Channel (4R-4Sv)	<u>P. decipiens</u>	12.60	0.0004	6.44	0.0112
		<u>A. simplex</u>	166.24	≤0.0001	0.06	0.8103
		<u>C. osculatum</u>	90.92	≤0.0001	27.39	≤0.0001
Whale Bank (30b)	vs. Scotian Shelf (4VS-4W)	<u>A. simplex</u>	400.22	≤0.0001	94.10	0.0001
Esquiman Channel (4R-4Sv)	vs. Southern Gulf Offshore (4T)	<u>P. decipiens</u>	11.20	0.0008	1.32	0.2514
		<u>A. simplex</u>	862.84	≤0.0001	42.79	≤0.0001
		<u>C. osculatum</u>	665.75	≤0.0001	122.84	≤0.0001
Western Bank (4Wj)	vs. Emerald Bank (4Wl)	<u>P. decipiens</u>	37.50	≤0.0001	0.91	0.3392
		<u>A. simplex</u>	12.42	0.0004	10.53	0.0012
Emerald Bank (4Wl)	vs. Roseway Bank (4Xo)	<u>P. decipiens</u>	3.50	0.0614	1.00	0.3181
		<u>A. simplex</u>	10.13	0.0015	12.46	0.0004
Roseway Bank (4Xo)	vs. Browns Bank (4Xp)	<u>P. decipiens</u>	5.36	0.0206	1.24	0.2661
		<u>A. simplex</u>	22.46	≤0.0001	3.82	0.0508
Browns Bank (4Xp)	vs. Grand Manan Basin (4Xrs)	<u>P. decipiens</u>	38.96	≤0.0001	0.05	0.8177
		<u>A. simplex</u>	23.24	≤0.0001	5.35	0.0207
Browns Bank (4Xp)	vs. Georges Bank-Fundian Channel (5Zej)	<u>P. decipiens</u>	27.31	≤0.0001	12.40	0.0004
		<u>A. simplex</u>	29.88	≤0.0001	5.86	0.0155
Grand Manan Basin (4Xrs)	vs. Georges Bank-Fundian Channel (5ZEj)	<u>P. decipiens</u>	122.02	≤0.0001	11.59	0.0007
		<u>A. simplex</u>	0.27	0.6066	0.16	0.6915

a. Contrasts based on two-way ANOVAs in Table 5.

TABLE 7. Prevalence and abundance of larval anisakines in flatfishes from Whale Bank (30b), the northeastern Gulf of St. Lawrence (4R) and southwestern Nova Scotia (4X and 5ZEj)

Host		Larval anisakines detected								
		<u>P. decipiens</u>			<u>A. simplex</u>			<u>C. osculatum</u>		
		Prevalence	Abundance	Density in b fillets	Prevalence	Abundance	Density in b fillets	Prevalence	Abundance	
Sample No	Location and date	Length range(cm)	n							
<u>American plaice</u>										
H23	Whale Bank (30b)	≤40	41	7	0.07	0.64	56	1.32	0.43	24
	Jun 84	41-45	26	4	0.04	0.20	88	4.12	1.01	42
		46-50	22	14	0.14	0.18	95	8.68	1.27	36
		≥51	26	15	0.15	0.07	100	23.12	0.82	81
	Total		115	10	0.10	0.18	81	8.29	0.88	43
<u>American plaice</u>										
H17	North Esquimaux Channel (4Rab)	≤30	56	13	0.20	5.45	16	0.23	0	4
	Jan 84	31-35	63	25	0.38	4.95	56	1.63	0.90	16
		36-40	39	33	0.41	3.11	49	2.00	0.41	30
		41-45	28	29	0.61	3.02	93	8.04	0.75	58
		46-50	10	30	0.50	2.13	100	15.40	0.43	43
		≥51	11	45	0.91	1.43	100	31.55	1.43	100
	Total		207	25	0.40	3.19	53	4.44	0.75	26
<u>American plaice</u>										
H18	South Esquimaux Channel (4Rab)	≤30	31	18	0.35	11.14	6	0.09	0	0
	Jan 84	31-35	24	21	0.38	5.04	7	0.13	0	0
		36-40	17	12	0.18	1.46	25	1.25	0	0
		41-45	18	39	0.50	2.50	50	1.63	0	0
		46-50	9	78	1.56	5.42	38	2.25	0	60
		≥51	6	50	1.33	2.97	67	21.83	1.11	75
	Total		108	28	0.51	4.01	21	2.30	0.23	12
<u>American plaice</u>										
H22	East of Emerald Basin (4W1)	≤20	31	16	0.16	26.79				
	Mar 84	21-30	19	0	0	0				
	Total		50	10	0.10	5.39				
<u>American plaice</u>										
H16	Sambro (4Xm)	≤30	37	54	0.95	25.74				
	Jan 84	31-35	124	53	1.19	15.75				
		36-40	63	54	1.24	10.80				
		41-45	16	75	2.56	11.74				
		46-50	21	67	1.38	4.95				
		≥51	19	53	1.84	4.76				
	Total		280	56	1.30	10.54				
<u>American plaice</u>										
H14	Roseway area (4Xo)	≤20	74	8	0.09	7.72				
	Jul-Oct 83	21-25	83	40	0.48	29.30				
		26-30	56	36	0.57	24.00				
		31-35	54	57	0.81	19.64				
		≥36	17	53	0.76	5.67				
	Total		284	35	0.48	16.71				

TABLE 7 (continued)

Host		Larval anisakines detected									
		<u>P. decipiens</u>					<u>A. simplex</u>			<u>C. oeculatum</u>	
Sample No	Location and date	Length range (cm)	n	Prevalence	Abundance	Density in b fillets	Prevalence	Abundance	Density in b fillets	Prevalence	Abundance
<u>American plaice</u>											
H13	Baccaro-Lahave area (40k)	30	14	29	0.79	20.75					
		31-35	56	39	0.66	8.84					
	Sep 83	36-40	40	50	0.65	6.21					
		≥41	22	23	0.36	1.39					
	Total		132	39	0.62	5.59					
<u>American plaice</u>											
H15	East Browns-Baccaro area (40k)	25	68	44	0.87	53.19					
		26-30	33	30	0.48	12.77					
	Jul-Oct 83	≥31	21	43	0.67	6.73					
	Total		122	40	0.73	20.03					
<u>American plaice</u>											
H21	West Browns Bank (40p)	30	6	33	1.67	52.50					
		31-40	23	52	1.70	17.21					
	Mar 84	≥41	10	50	4.20	16.58					
	Total		39	49	2.26	17.84					
<u>American plaice</u>											
H20	Jordan Basin (40q)	20	20	75	1.65	154.69					
		21-25	28	71	2.32	107.85					
	Mar 84	26-30	31	81	3.06	74.84					
		31-35	37	89	4.03	55.99					
		36-40	20	75	1.90	13.70					
		≥41	33	64	1.09	3.32					
	Total		169	76	2.46	22.67					
<u>American plaice</u>											
H19	Lower Bay of Fundy (40rs)	20	23	35	0.65	81.52					
		21-30	27	52	1.63	52.72					
	Jul 83-Mar 84	31-40	28	89	5.82	71.32					
		≥41	17	82	5.12	17.91					
	Total		95	64	3.25	37.86					
<u>American plaice</u>											
H12	Georges Bank (52ej)	30	44	7	0.09	2.45					
		31-35	63	10	0.16	2.03					
	Jun 83	36-40	39	23	0.56	4.61					
		41-45	22	14	0.18	1.02					
		46-50	7	29	0.29	1.07					
		≥51	10	30	0.30	0.73					
	Total		183	14	0.26	2.12					

TABLE 7 (continued)

Host		Larval anisakines detected							
		<i>P. decipiens</i>				<i>A. simplex</i>		<i>C. ceculatum</i>	
Sample Location No ^a	Length range (cm)	n	Prevalence	Abundance	Density in fillets ^b	Prevalence	Abundance	Prevalence	Abundance
<u>Gray sole</u>									
07 Baccaro-Lahave (4Xo) Sep 83	≤35	6	0	0	0				
	36-40	26	12	0.12	1.37				
	41-45	19	11	0.16	1.31				
	46-50	18	17	0.33	1.77				
	≥51	11	45	0.64	2.30				
	Total	80	16	0.24	1.68				
<u>Gray Sole</u>									
08 Jordan Basin (4Xq) Mar 84	≤35	15	20	0.20	4.35				
	36-40	20	45	0.70	6.10				
	41-45	44	52	1.16	7.11				
	46-50	29	72	2.38	10.96				
	≥51	21	81	1.81	5.82				
	Total	29	57	1.36	7.58				
<u>Yellowtail Flounder</u>									
04 West Browns Bank (4Xp) Mar 84	≤25	29	3	0.03	1.56				
	26-30	47	11	0.11	2.64				
	31-35	60	12	0.12	1.63				
	≥36	30	0	0	0				
	Total	166	8	0.08	1.27				

a. Refer to Fig. 11.

b. Number of nematodes per kg fillet.

TABLE.8 Distributions of larval anisakines in the tissues of Whale Bank(30b), and and northeastern Gulf (4R) plaice.

Host length range(cm)	Larval anisakines				
	Species	n	Percent in		
			Body cavity	Napes	Fillets
≤30	<u>P. decipiens</u>	24	0	0	100
	<u>A. simplex</u>	17	88.24	5.88	5.88
31-40	<u>P. decipiens</u>	54	3.70	0	96.30
	<u>A. simplex</u>	260	89.62	7.31	3.08
41-50	<u>P. decipiens</u>	60	6.67	1.67	91.67
	<u>A. simplex</u>	831	88.57	9.39	2.05
≥51	<u>P. decipiens</u>	22	18.18	9.09	72.72
	<u>A. simplex</u>	934	86.30	11.46	2.25
Total	<u>P. decipiens</u>	160	6.25	1.88	91.88
	<u>A. simplex</u>	2,042	87.66	10.04	2.30

TABLE.9 Two-way Type-III ANOVAs for variations in abundance of larval anisakines with sample and length of American plaice from eastern Canada^a.

Source of variation	Nematode species	Degrees of freedom	Type-III mean square	F	P > F
<u>Main effects</u>					
Sample	<u>P. decipiens</u>	18	1.520	25.85	≤0.0001
	<u>A. simplex</u>	18	3.326	280.43	≤0.0001
	<u>C. osculatum</u>	18	0.965	30.37	≤0.0001
Host length	<u>P. decipiens</u>	5	0.525	8.94	≤0.0001
	<u>A. simplex</u>	5	1.024	86.37	≤0.0001
	<u>C. osculatum</u>	5	0.377	11.88	≤0.0001
<u>Interaction</u>					
Sample X host length	<u>P. decipiens</u>	90	0.223	3.79	≤0.0001
	<u>A. simplex</u>	90	0.433	36.53	≤0.0001
	<u>C. osculatum</u>	90	0.152	4.79	≤0.0001
<u>Error</u>	<u>P. decipiens</u>	4,387	0.059		
	<u>A. simplex</u>	4,387	0.011		
	<u>C. osculatum</u>	4,387	0.032		

a. Includes data from McClelland et al. (1983a and b).

TABLE.10 Two-way contrasts of abundances of larval anisakines in stratified samples of American plaice from eastern Canada.

a Contrast		Nematode species	Sample means		Sample means X host length	
			F	PzF	F	PzF
Whale Bank (30b)	vs. North Esquiman Channel (4Rab)	<u>P. decipiens</u>	3.30	0.0692	0.16	0.6880
		<u>A. simplex</u>	1.37	0.2417	47.11	≥0.0001
		<u>C. osculatum</u>	2.45	0.1178	0.90	0.3433
Whale Bank (30b)	vs. South Esquiman Channel (4Rcd)	<u>P. decipiens</u>	7.63	0.0058	0.96	0.3260
		<u>A. simplex</u>	270.17	≥0.0001	8.81	0.0030
		<u>C. osculatum</u>	4.27	0.0389	0.05	0.8179
North Esquiman Channel (4Rab)	vs. South Esquiman Channel (4Rcd)	<u>P. decipiens</u>	2.56	0.1100	1.14	0.2864
		<u>A. simplex</u>	618.31	≥0.0001	286.34	≥0.0001
		<u>C. osculatum</u>	17.93	≥0.0001	3.02	0.0822
Esquiman Channel (4Rabcd)	vs. Magdalen Shoal (4T)	<u>P. decipiens</u>	6.28	0.0123	7.06	0.0079
South Esquiman Channel (4Rcd)	vs. Magdalen Shoal (4T)	<u>A. simplex</u>	106.51	≥0.0001	42.00	≥0.0001
		<u>C. osculatum</u>	5.38	0.0204	12.71	0.0004
Browns LaHave-Roseway (4Xo)	vs. Western Bank (4Wj)	<u>P. decipiens</u>	21.09	≥0.0001	0.01	0.9345
Browns LaHave-Roseway (4Xo)	vs. Sambro (4Xm)	<u>P. decipiens</u>	24.24	≥0.0001	1.79	0.1816
Browns LaHave-Roseway (4Xo)	vs. Jordan Basin (4Xq)	<u>P. decipiens</u>	45.06	≥0.0001	4.90	0.0269
Browns LaHave-Roseway (4Xo)	vs. Georges Bank (5Ze)	<u>P. decipiens</u>	5.30	0.0214	0.60	0.4400
Jordan Basin (4Xq)	vs. Grand Manan Basin (4Xrs)	<u>P. decipiens</u>	20.71	≥0.0001	11.10	0.0009
Jordan Basin (4Xq)	vs. Georges Bank (5Zej)	<u>P. decipiens</u>	81.86	≥0.0001	8.89	0.0029

a. Contrasts based on two-way ANOVAs in Table 9.

TABLE.11 Two-way type-III ANOVAs and contrasts of variations in sealworm (*P. decipiens*) abundance in 4T, 4VN, 4VS, 4W and 4X gray sole (1980-84).

Source of variation	Degrees of freedom	Type-III mean square	F	P2F
<u>Main effects</u>				
Host sample	7	0.533	23.68	≤0.0001
Host length	4	0.724	32.18	≤0.0001
<u>Interaction</u>				
Host sample X host length	28	0.050	2.22	0.0003
<u>Error</u>	1,260	0.023		
<u>Contrasts</u>				
Baccaro-LaHave (4Xno) vs. Jordan Basin (4Xq) sample	1	1.474	65.49	≤0.0001
Baccaro-LaHave (4Xno) vs. Jordan Basin (4Xq) (sample X host length)	1	0.137	6.08	0.0138
Baccaro-LaHave (4Xno) vs. Sable Island Bank (4Wf) (sample)	1	0.200	8.99	0.0029
Baccaro-LaHave (4Xo) vs. Sable Island Bank (4Wf) (sample X host length)	1	0.003	0.12	0.7252
Jordan Basin (4Xq) vs. Sable Island Bank (4Wf) (sample)	1	0.290	12.88	0.0003
Jordan Basin (4Xq) vs. Sable Island Bank (4Wf) (sample X host length)	1	0.116	5.15	0.0234

TABLE.12 Prevalence, abundance and density of sealworm (*P. decipiens*) in the fillets of eastern Canadian plaice 31cm - 40cm in length.

Host				<u>P. decipiens</u>		
Sample No ^a	Date	Location	n	Prevalence	Abundance	Density ^b
1	Jul 83	Cartwright Channel (2J)	125	6	0.06	0.64
2	Nov 83	Hamilton Inlet (2J)	194	2	0.02	0.22
3	Dec 83	3K Offshore	232	0	0	0
4	Jul 83	Notre Dame Bay (3K)	200	51	50.01	0.05
5	Jul 83	Off Catalina Harbour (3L)	208	1	0.01	0.03
6	Oct 83	Grand Bank (3L)	178	1	0.01	0.11
7	Jul 83	Grand Bank (3L)	99	0	0	0
8	Nov 83	Grand Bank (3L)	159	0	0	0
9	Dec 83	Grand Bank (3N)	187	0	0	0
10	Nov 83	Tail of the Bank (3N)	190	0	0	0
11	May 84	Whale Bank (3O)	193	2	0.09	0.83
12	Jul 83	Burin Peninsula (3PS)	207	25	0.34	3.23
13	Apr 84	East St. Pierre Bank (3PS)	77	10	0.30	3.03
14	Sep 83	West St. Pierre Bank (3PS)	83	19	0.37	4.65
15	Oct 83	Port-aux-Basques (3PN)	191	23	0.40	3.51
16	Oct 83	St. George's Bay (4R)	212	22	0.49	4.07
17	Oct 83	Cape St. George (4R)	198	16	0.25	2.58
18	Sep 83	Long Point (4R)	60	10	0.13	1.28
19	Oct 83	Point Riche (4R)	176	15	0.19	2.05
20		Off Ferrolle Point (4R/4S)	60	43	0.68	8.11
21	Jan 84	Esquiman Channel (4R)	143	25	0.36	3.72
22	Jun 83	South Anticosti Island (4S)	157	22	0.27	3.06
23	Oct 83	West Anticosti Island (Inshore) (4S)	95	14	0.15	1.65
24	Oct 83	West Anticosti Island (Offshore) (4S)	122	19	0.26	3.74
25	Oct 83	North Shore Quebec (4S)	154	15	0.25	2.59
26	Jun 83	Laurentian Channel off Gaspé (4T)	150	25	0.48	4.32
27	Aug 83	Baie des Chaleurs (4T)	150	17	0.18	2.70
28	Jun 83	Shediac Valley off Miscou (4T)	170	20	0.33	3.57
29	Aug 83	Bradelle Bank (4T)	146	17	0.18	1.64
30	Jun 83	Shediac Valley off Miramichi (4T)	141	42	0.74	7.43

TABLE.12 (continued)

Sample No ^a	Date	Host		<i>P. decipiens</i>		
		Location	n	Prevalence	Abundance	Density ^b
31	Jun 83	Off Point Esouminac (4T)	187	35	0.55	5.63
32		Southwest of Magdalen Islands (4T)	43	33	0.49	5.87
33	Dec 83	^c Souris (4T)	193	21	0.32	3.00
34	Aug 83	Cape George (4T)	186	78	1.71	14.58
35	Jul 83	Chéticamp (4T)	72	47	1.31	11.72
36	Nov 83	Chéticamp (4T)	113	57	1.13	16.67
37	Nov 83	Pleasant Bay (4T)	200	50	1.13	11.44
38	Oct 80	Ingonish (4VN)	130	55	1.14	10.88
39	Jul/Oct 83	Edge of Ground (4VN)	90	67	1.59	18.56
40	Nov 83	Louisburg Hole (4VN)	74	62	1.57	16.35
41	Oct 83	Central Misaine Bank (4VS)	76	41	0.68	10.48
42	Oct 83	Artimon Bank (4VS)	48	69	2.13	29.65
43	Jul/Oct 83	Misaine Channel (4VS)	141	57	1.52	24.39
44	Jul/Oct 83	East Banquereau (4VS)	220	63	1.73	21.56
45	Jul/Oct 83	West Banquereau (4VS)	204	74	2.87	38.15
46	Jul/Oct 83	Canso Bank (4W)	83	52	0.95	11.35
47	Nov 83	Canso Hole (4W)	154	77	2.08	24.42
48	Jul/Oct 83	Middle Bank (4W)	71	89	3.92	52.92
49	Jul/Oct 83	Sable Island Bank (4W)	132	95	5.17	62.32
50	Jul/Oct 83	Western Bank (4W)	100	95	6.58	100.71
51	Jan 84	Sambro (4X)	187	53	1.20	13.59
52	Jul/Oct 83	Roseway Area (4X)	67	57	0.79	13.61
53	Jul/Oct 83	East Browns-Baccaro-LaHave (4X)	114	43	0.64	6.84
54	Jul 83/ Mar 84	Lower Fundy-Jordan Basin (4X)	85	86	4.12	45.34
55	Jun 83	Georges Bank (5ZEJ)	102	15	0.29	3.30

a. Refer to Fig. 16

b. Average number per kg fillet.

c. Port sample - exact geographic origin unknown.

TABLE 13 One-way ANOVAs for variations in sealworm (*P. decipiens*) abundance in the fillets of eastern Canadian plaice 31 cm-40 cm in length: contrasts of samples according to geographic origins.

Source of variation		Degrees of freedom	Mean square	F	a P	χ^2	a P
<u>Sample</u>		54	4.131	104.21	≤0.0001*		
<u>Error</u>		7,610	0.040				
<u>Contrasts</u>							
Hamilton Inlet Bank (2Je)	vs. N.E. Wfld. and Grand Bank (3K, 3L and 3N)	1	0.035	0.87	0.3505	4.27	0.0370
Whale Bank (30b)	vs. N.E. Wfld. and Grand Bank (3K, 3L and 3N)	1	0.016	0.39	0.5303	1.30	0.2536
Whale Bank (30b)	vs. St. Pierre Bank and southern Wfld. (3P)	1	0.841	21.21	≤0.0001*	53.26	≤0.0001*
Western Wfld.(St. Georges Bay to Pt. Riche) (4Rbcd)	vs. 3P	1	0.042	1.06	0.3026	5.24	0.0209
Western Wfld. (St. Georges Bay to Pt. Riche) (4Rbcd)	vs. Ferolle Pt. (4Ra)	1	0.632	15.93	≤0.0001*	15.89	≤0.0001*
Western Wfld. (St. Georges Bay to Pt. Riche) (4Rbcd)	vs. Anticosti and North Shore (4Sisy)	1	0.002	0.06	0.8077	0.03	0.8553
Western Wfld.(St. Georges Bay to Pt. Riche) (4Rbcd)	vs. Miscou to Magdalens (4Tfkn)	1	0.071	1.60	0.1793	0.33	0.5759
Western Wfld. (St. Georges Bay to Pt. Riche) (4Rbcd)	vs. Châticaup to Pleasant Bay (4Tg)	1	6.264	158.03	≤0.0001*	129.10	≤0.0001*
Miscou to Magdalens (4Tfkn)	vs. Anticosti and North Shore (4Sisy)	1	0.089	2.24	0.1342	0.84	0.6387
Miscou to Magdalens (4Tfkn)	vs. Miramichi area (4Tl)	1	1.101	27.78	≤0.0001*	39.36	≤0.0001*
Miscou to Magdalens (4Tfkn)	vs. Châticaup to Pleasant Bay (4Tg)	1	5.283	133.28	≤0.0001*	121.26	≤0.0001*
Châticaup to Pleasant Bay (4Tg)	vs. Cape George (4Tg)	1	1.838	46.37	≤0.0001*	31.91	≤0.0001*
Châticaup to Pleasant Bay (4Tg)	vs. 4VN	1	0.842	21.25	≤0.0001*	12.79	0.0005
4VN	vs. 3P	1	9.349	235.84	≤0.0001*	140.26	≤0.0001*
4VN	vs. Artimon, east Banquereau and Missine Channel (4VSc)	1	0.003	0.07	0.7984	0.11	0.7385
Artimon, east Banquereau and Missine Channel (4VSc)	vs. Missine Bank (4VSc)	1	1.541	38.86	≤0.0001*	23.83	≤0.0001*
Artimon, east Banquereau and Missine Channel (4VSc)	vs. West Banquereau (4VSc)	1	1.513	38.16	≤0.0001*	19.53	≤0.0001*
Missine Bank (4VSc)	vs. Canoe Bank (4Wd)	1	0.153	3.85	0.0498	2.93	0.0829
Canoe Bank (4Wd)	vs. Canoe Hole (4Wde)	1	1.544	38.94	≤0.0001*	23.61	≤0.0001*
Canoe Bank (4Wd)	vs. Middle Bank (4We)	1	5.134	129.53	≤0.0001*	63.89	≤0.0001*
West Banquereau (4VSc)	vs. Middle Bank (4We)	1	1.242	31.33	≤0.0001*	11.78	0.0007
West Banquereau (4VSc)	vs. Sable Island Bank (4Wh)	1	5.484	138.35	≤0.0001*	54.17	≤0.0001*
Sable Island Bank (4Wh)	vs. Middle Bank (4We)	1	0.555	13.99	0.0002*	5.76	0.0156
Sable Island Bank (4Wh)	vs. Western Bank (4Wj)	1	0.544	13.72	0.0002*	6.16	0.0126
Western Bank (4Wj)	vs. Sambro, Browns-LaHave and Roseway (4Xmo)	1	26.278	662.93	≤0.0001*	321.20	≤0.0001*
Sambro, Browns-LaHave and Roseway (4Xmo)	vs. Jordan and Grand Manan basins (4Xgra)		8.281	208.90	≤0.0001*	78.39	≤0.0001*
Sambro, Browns-LaHave and Roseway (4Xmo)	vs. Georges Bank (5ZEj)	1	1.595	40.24	≤0.0001*	47.47	≤0.0001*

a. Bonferroni: significant (*) if P ≤0.00029 for 173 contrasts.

TABLE.14 Ranked sampling locations with mean transformed sealworm (*P. decipiens*) counts in 31 cm-40 cm plaice and cod, (≤ 50 , 51-70 and ≥ 71 cm in length) at each location.

Host sample		<i>P. decipiens</i> : mean transformed ($\log_{10}(n+1)$) count in			
Rank	Geographic origin	Plaice	Cod		
		(31cm-40cm)	≤ 50 cm	51-70 cm	≥ 71 cm
1	Whale Bank (30b)	0.011	0.004	0.045	0.212
2	Bradelle Bank (4Tk)	0.050	0.167	0.320	0.982
3	Georges Bank (5ZEj)	0.062	0.125	0.111	0.408
4	Esquiman Channel (4R-4Sv)	0.093	0.050	0.159	0.785
5	East Banquereau Bank (4VSc)	0.115	0.216	0.402	0.837
6	Misaine Bank (4VSb)	0.142	0.130	0.320	0.704
7	Browns-LaHave (4Xop)	0.162	0.129	0.245	0.603
8	Edge of Ground (4VN)	0.192	0.180	0.312	0.592
9	Point Escuminac (4Ti)	0.196	0.168	0.427	0.699
10	Roseway (4Xo)	0.207	0.135	0.337	0.814
11	Chebucto Head (4Xm)	0.291	0.327	0.730	1.369
12	Ingonish (4VN)	0.309	0.310	0.431	0.891
13	Southeast Gulf of St. Lawrence (4Tg)	0.361	0.314	0.634	1.094
14	Canso Bank Hole (4Wd)	0.389	0.203	0.563	1.173
15	Edge of Western Bank (4Wj)	0.395	0.348	0.706	1.103
16	West Banquereau Bank (4VSc)	0.433	0.192	0.619	0.854
17	Sable Island Bank (4Wf)	0.525	0.362	1.029	1.288
18	Jordan and Grand Manan basins (4Xqrs)	0.556	0.227	0.533	0.650
19	Middle Bank (4We)	0.587	0.200	0.655	--
20	Western Bank (4Wh)	0.794	0.359	0.813	1.319

TABLE.15 Comparisons of weighted regressions for geographic variations in sealworm (*P. decipiens*) abundance in eastern Canadian (30, 4R, 4T, 4VN, 4VS, 4W & 5ZE) cod and plaice.

Plaice ^a				Cod ^b				$b_1 = b_2$		
Length range(cm)	b_1^c	F	P	Length range(cm)	b_2^c	F	P	F ^d	χ^2^e	P
31-40	0.0330	186.20 ^f	\$0.0001*	\$50	0.0116	17.70 ^f	\$0.0003*	33.1307		\$0.0001*
31-40	0.0330	277.39 ^g	\$0.0001*	51-70	0.0355	49.21 ^g	\$0.0001*		0.2017	\$0.66
31-40	0.0330	277.39 ^g	\$0.0001*	\$71	0.0280	7.45 ^g	\$0.02*		0.2283	\$0.64
31-40	0.0330	277.39 ^g	\$0.0001*	Total	0.0211	21.79 ^g	\$0.0001*		5.8762	\$0.015*

- a. Plaice samples ranked in ascending order of mean transformed ($\log_{10}(n+1)$) sealworm counts.
- b. Cod samples assigned same ranks as plaice samples from corresponding locations.
- c. Regression coefficient of transformed worm count on rank.
- d. Where variances of regressions did not differ, equality of b_1 and b_2 was tested by an F-test (Bliss 1967).
- e. Where variances of regressions differed, equality of b_1 and b_2 was tested by a χ^2 method (Armitage 1971).
- f. Where scatters did not differ significantly, significance (*) of regression coefficients were tested against the pooled scatter mean squares of both hosts.
- g. Where scatters differed, significance (*) of regression coefficients were tested against the scatter mean squares of the respective hosts.

TABLE.16 Long-term variations in abundances of larval anisakines (*P. decipiens* and *A. simplex*) in the fillets of eastern Canadian cod.

Host		Larval anisakines detected							
Location	Length range(cm)	a 1983-84				b 1946-56			
		n	Prevalence	Abundance	Density	n	Prevalence	Abundance	Density
30 ^b	31-50	84	11 (4)	0.13 (0.06)	0.65	922	3	0.03	0.04
	51-70	98	23 (13)	0.30 (0.16)	0.55				
	\$71	24	46 (42)	1.21 (0.96)	0.70				
4R-4S ^b	31-50	106	25 (13)	0.32 (0.16)	1.52	207	8	0.09	0.40
	51-70	111	54 (33)	1.06 (0.59)	2.09	507	22	0.34	0.63
	\$71	5	100 (100)	6.20 (5.80)	4.49	228	36	0.63	0.51
4Xo ^c (Roseway Bank)	31-50	149	33 (32)	0.59 (0.58)	2.41	150*	15	0.26	0.86
	51-70	117	70 (70)	1.71 (1.70)	2.94	400**	15	0.32	0.40
	\$71	16	88 (88)	9.00 (9.00)	6.45	--	--	--	--
4Xnp ^c (Browns LaHave)	31-50	82	32 (32)	0.55 (0.55)	1.96	400*	9	0.18	0.59
	51-70	133	58 (58)	1.05 (1.05)	1.83	2,050**	8	0.16	0.24
	\$71	22	82 (82)	8.55 (8.55)	4.58	450***	8	0.14	0.07
4Xrs ^{c,d} (Lower Bay of Fundy)	31-50	42	43 (43)	1.26 (1.26)	7.40	100*	66	1.00	--
	51-70	120	83 (83)	3.51 (3.51)	5.22	100**	99	3.40	--
	\$71	28	82 (82)	6.68 (6.68)	3.77	50***	100	23.80	--

- a. Data from present study; figures in parentheses are prevalences and abundances of *P. decipiens* alone.
- b. 1947-53 data from Templeman et al. (1957); according to Templeman et al., 29% of the nematodes from 30 cod were *P. decipiens* and 71% *Anisakis* sp; 93% of nematodes from 4R-4S cod were *P. decipiens*.
- c. 1946-56 data on nematode abundances in graded cod fillets from Scott and Martin (1957); fillet grades - scrod (*), market (**) and steak (***) $n = \frac{\text{no. of fillets}}{2}$, prevalence = 1.5 x percent of fillets infected and abundance = 2 x no. of worms per fillet.
- d. Sample collected from Grand Manan Basin in present study, from Passamaquoddy Bay in Scott and Martin's study.

TABLE.17 Long-term variations in abundances of larval anisakines (*P. decipiens* and *A. simplex*) in the fillets of eastern Canadian plaice.

Host		Larval anisakines detected							
Location	Length range(cm)	1983-84 ^a				1946-56 ^b			
		n	Prevalence	Abundance	Density	n	Prevalence	Abundance	Density
30	31-40	234	6 (3)	0.11 (0.09)	1.05	284	0	0	0
	41-50	48	23 (4)	0.29 (0.04)	1.34				
	≥51	26	35 (4)	0.46 (0.04)	0.89				
3PS	31-40	367	23 (21)	0.37 (0.34)	5.26	42	7	0.07	0.75
4R	21-30	90	14 (14)	0.26 (0.26)	7.43	169	9	0.13	3.83
	31-40	143	27 (25)	0.39 (0.35)	4.17	55	9	0.09	0.95
	41-50	65	40 (34)	0.72 (0.65)	3.55	13	15	0.31	1.32
	≥51	17	71 (47)	1.47 (0.82)	3.30	1	0	0	0
4T (Bradelle Bank)	31-40	146	17 (17)	0.18 (0.18)	1.64	34	24	0.32	3.34
4V (Edge of Laurentian Channel)	31-40	432	64 (64)	1.72 (1.72)	20.67	61	3	0.07	0.68

a. Data from present study; figures in parentheses are prevalences and abundances of *P. decipiens* alone.

b. Data from Templeman et al. (1957); according to the authors, of the nematodes identified from 3P, 4R, 4T and 4V plaice, 100% were *P. decipiens*.

TABLE.18 Comparisons of sealworm (*P. decipiens*) abundances in samples of American plaice (31 cm-40 cm in length) collected at corresponding locations in 1980-82 and in 1983-84.

Host		<i>P. decipiens</i> in fillets			Contrast ^a			
Location	Time ^b	n	Prevalence	Abundance	F ^c	P2F	X ^{2c}	P2F
Miramichi area (4T)	Nov 80, Jun 81,	707	28	0.41	0.76	0.3831	16.52	0.0001*
	Jun 83	328	38	0.63				
Chéticamp (4T)	Nov 80,	42	45	1.00	1.35	0.2453	0.64	0.5697
	Jul/Nov 83	385	51	1.16				
Edge of Ground (4VN)	Mar 81,	55	40	1.00	14.17	0.0002*	7.91	0.0050*
	Jul/Nov 83	164	65	1.58				
Misaine Bank (4VS)	Feb 82	93	35	0.65	0.38	0.5390	0.32	0.5732
	Oct 83	76	41	0.68				
East Banquereau Bank (4VS)	May 82	59	31	0.46	43.75	≤0.0001*	37.53	≤0.0001*
	Jul/Oct 83	220	63	1.73				
Misaine Channel (4VS)	Mar 82	67	54	1.48	0.01	0.9395	0.27	0.9575
	Jul/Oct 83	141	57	1.52				
Sable Island Bank (4W)	Jul 82	78	87	3.21	34.58	≤0.0001*	16.37	0.0001*
	Jul/Oct 83	132	95	5.17				
Western Bank (4W)	Sep 82	69	72	2.16	158.58	≤0.0001*	72.31	≤0.0001*
	Jul/Oct 83	100	95	6.58				
Chebucto Head - Sambro (4X)	Mar 82	62	56	1.66	1.99	0.1581	0.94	0.6650
	Jan 84	187	53	1.20				

a. Contrasts of mean transformed ($\log_{10}(n+1)$) worm counts from ANOVAs of 65 samples of plaice 31-40 cm in length.

b. 1980-81 data from McClelland et al. (1983a); 1982 data from McClelland et al. (1983b); 1983-84 data from present study.

c. Bonferroni; significant (*) if $P \leq 0.0056$.

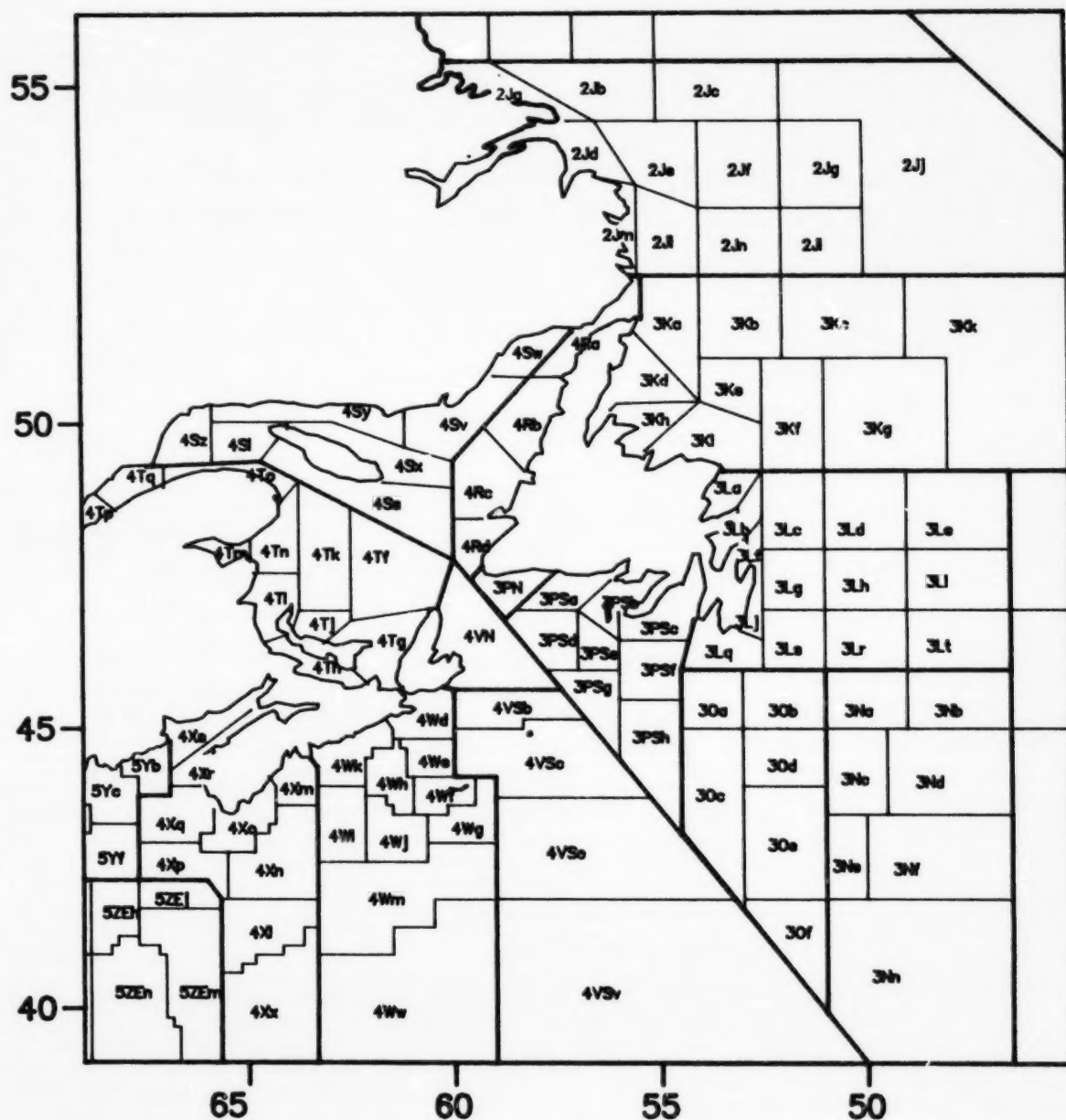


FIG. 1. NAFO divisions, subdivisions and unit areas for eastern Canada (Jones 1978). (Updates and corrections by G. Black, Fisheries Analyst, Resource Mapping and Graphic Illustration.)

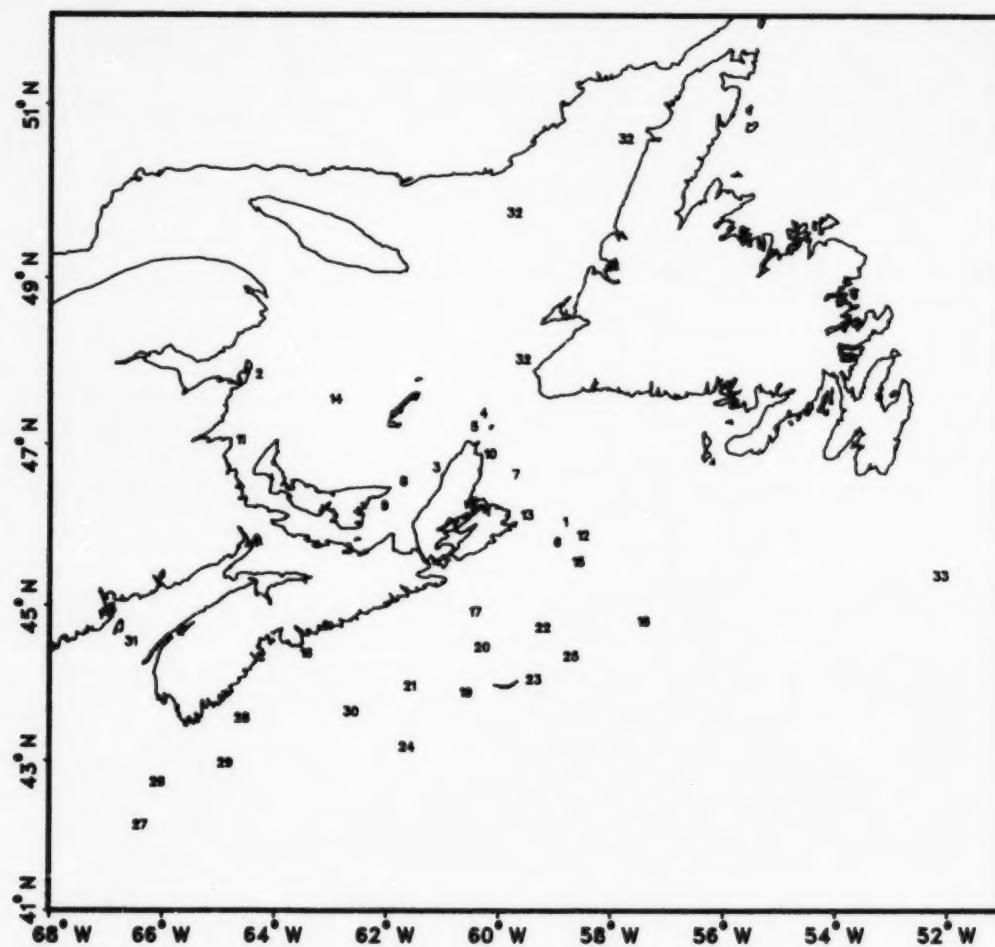


FIG. 2. Sampling locations for cod, 1980-84.

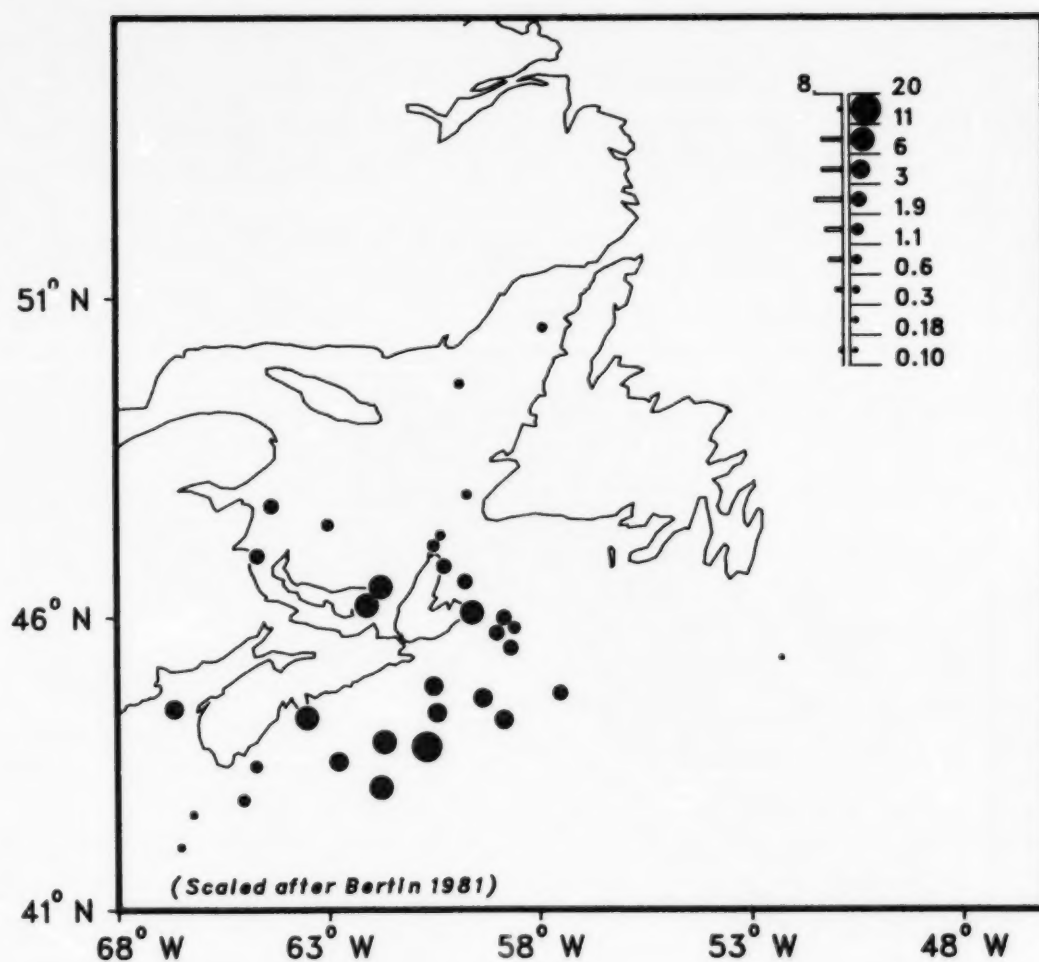


FIG. 3. Geographical variations in sealworm (*P. decipiens*) abundance in eastern Canadian cod, 51 cm–71 cm in length, 1980–84. (Diameters of symbols scaled according to nematode abundance; frequency distribution of fish according to nematode abundance also indicated on scale.)

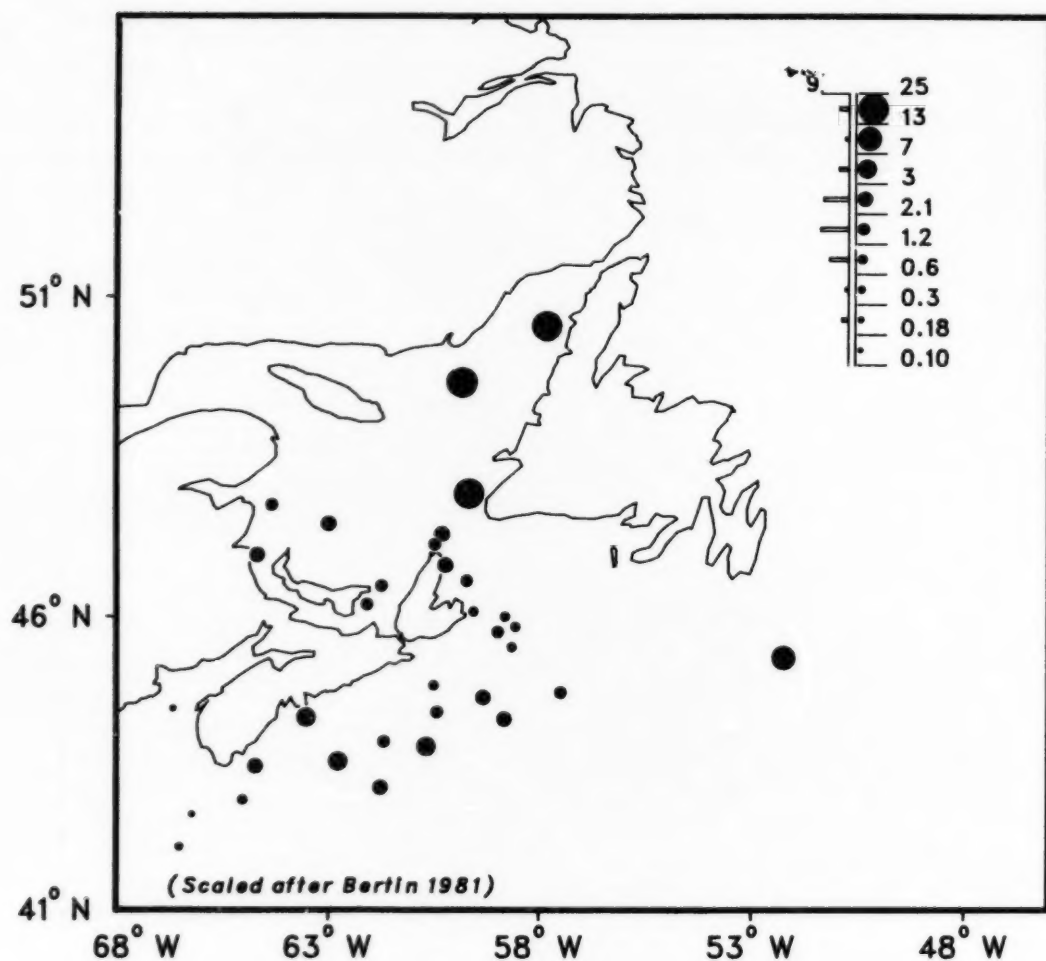


FIG. 4. Geographical variations in abundance of *A. simplex* larvae in eastern Canadian cod, 51 cm-70 cm in length, 1980-84. (Diameters of symbols scaled according to nematode abundance; frequency distribution of fish according to nematode abundance also indicated on scale.)

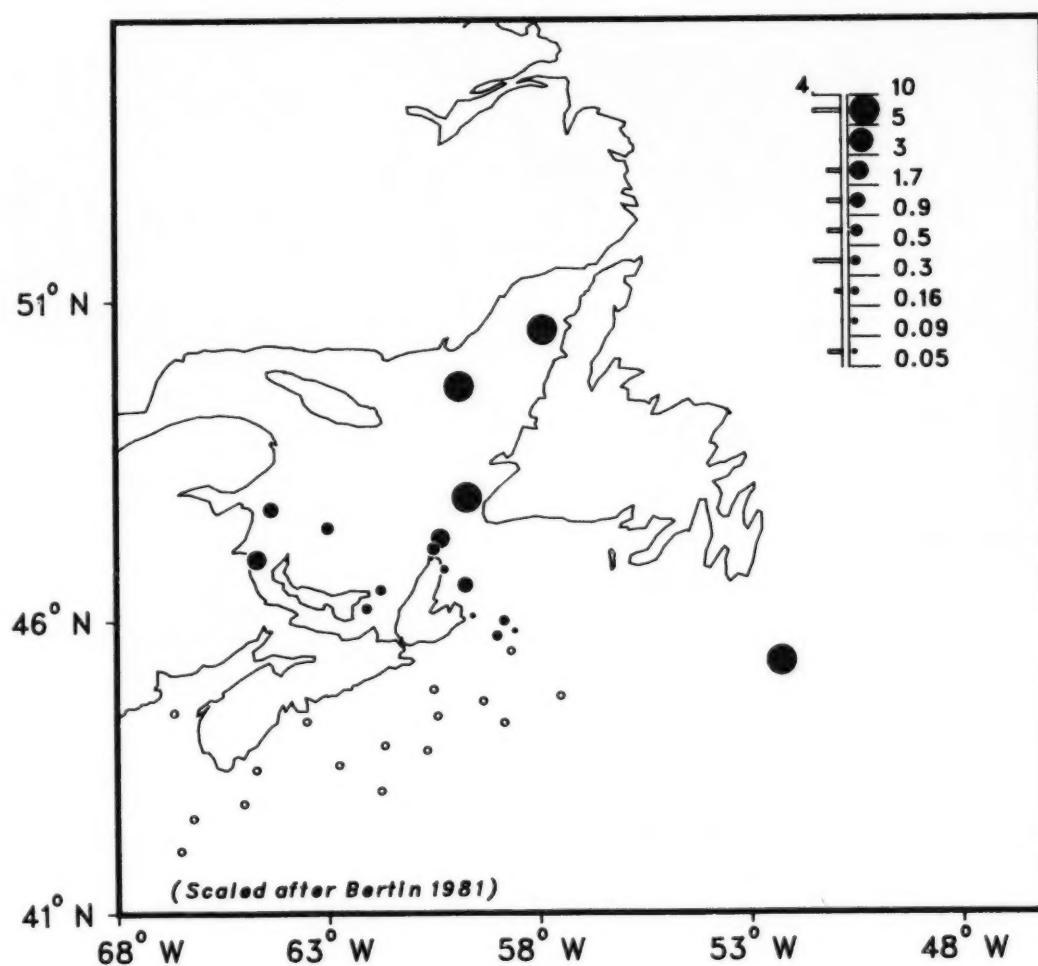


FIG. 5. Geographical variations in abundance of *C. osculatum* larvae in eastern Canadian cod, 51 cm-70 cm in length, 1980-84. ([o]=*C. osculatum* not detected; diameters of symbols scaled according to nematode abundance; frequency distribution of fish by nematode abundance also indicated on scale.)

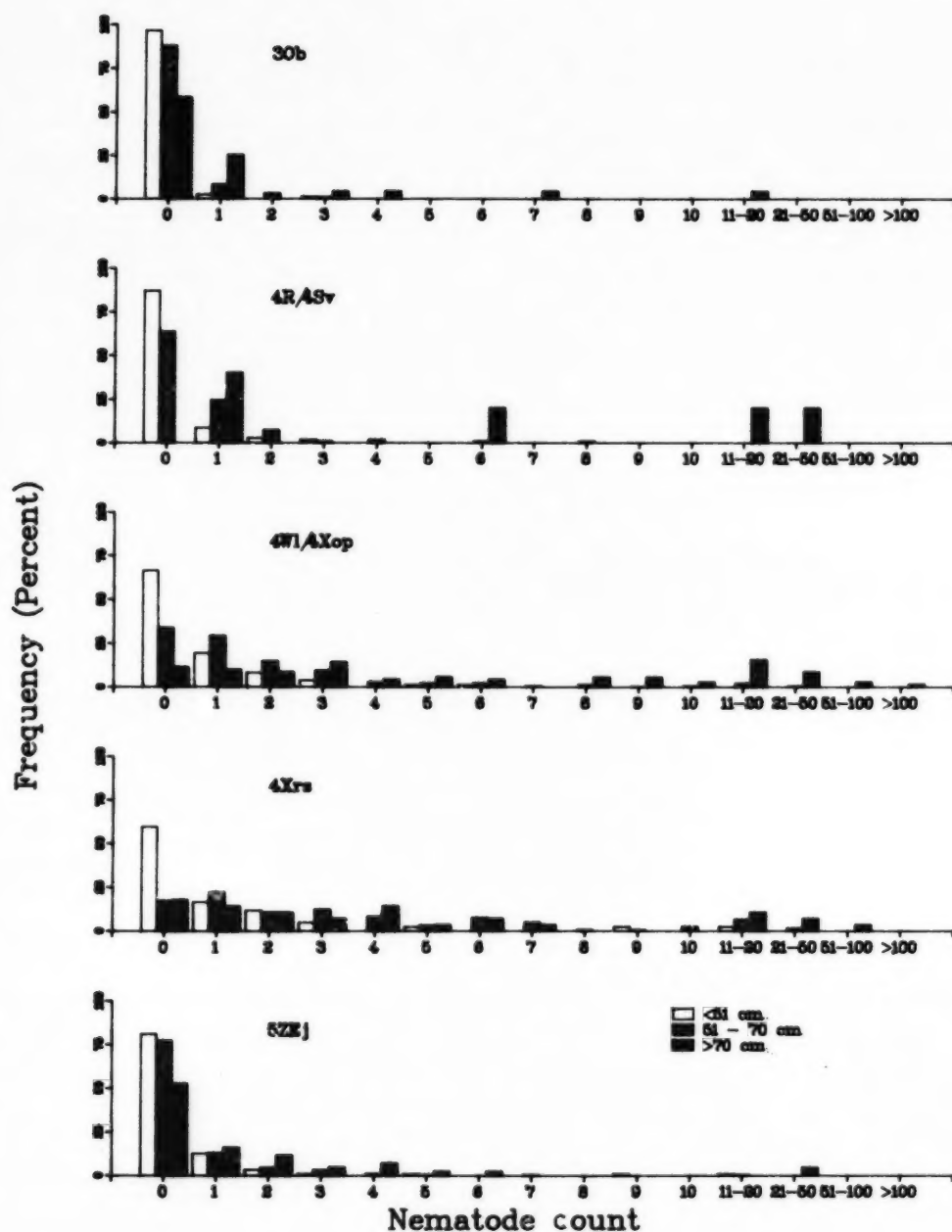


FIG. 6. Frequency distributions of sealworm (*P. decipiens*) counts in cod from Whale Bank (30b), the northeastern Gulf of St. Lawrence (4R-4Sv) and southwestern Nova Scotia (4W, 4X and 5ZEj): distributions for < 51, 51-70 and > 70-cm host length strata.

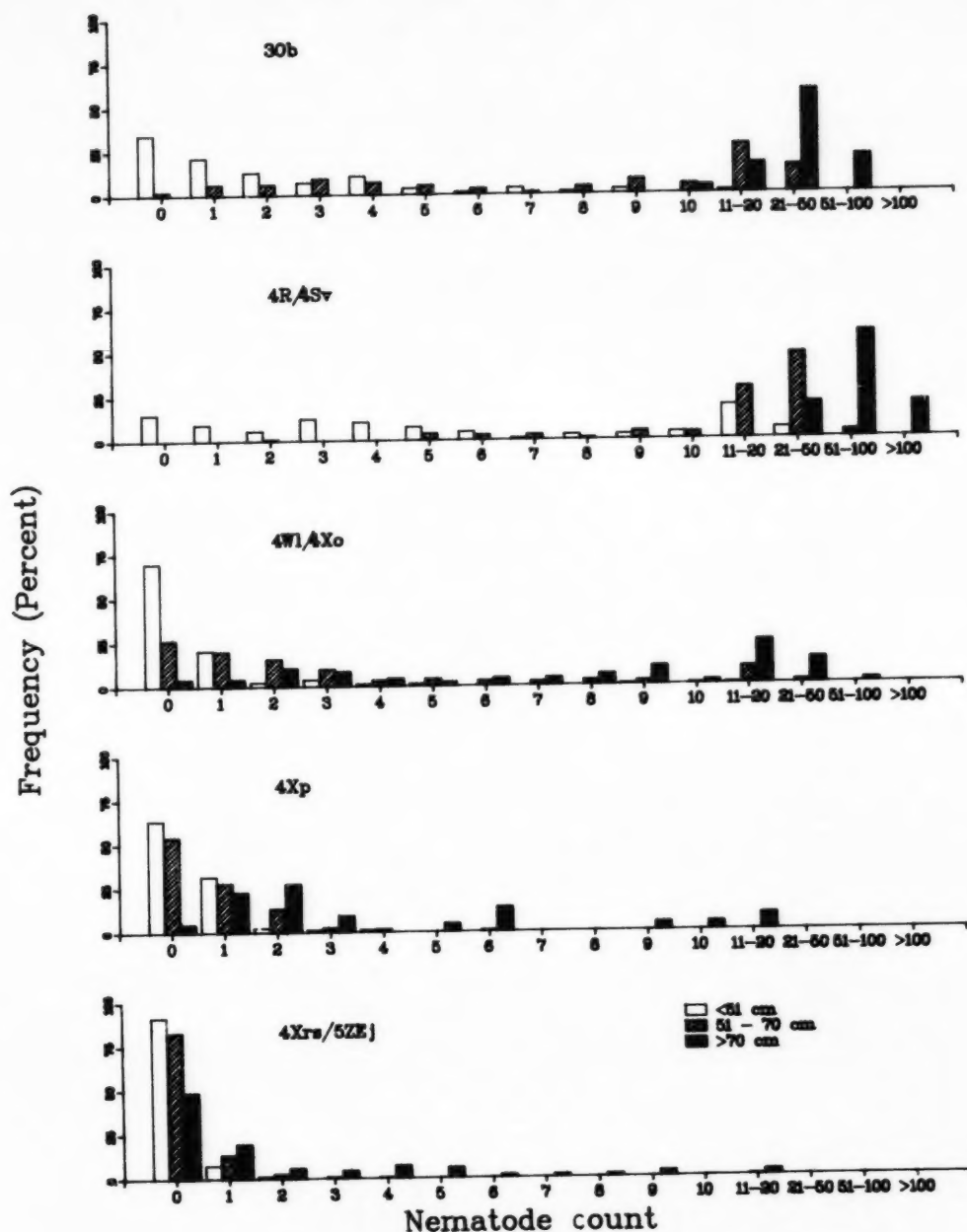


FIG. 7. Frequency distributions of *A. simplex* larvae in cod from Whale Bank (30b), the northeastern Gulf of St. Lawrence (4R-4Sv) and southwestern Nova Scotia (4W1, 4X and 5ZEj): distributions for <51, 51-70 and >70-cm host length strata.

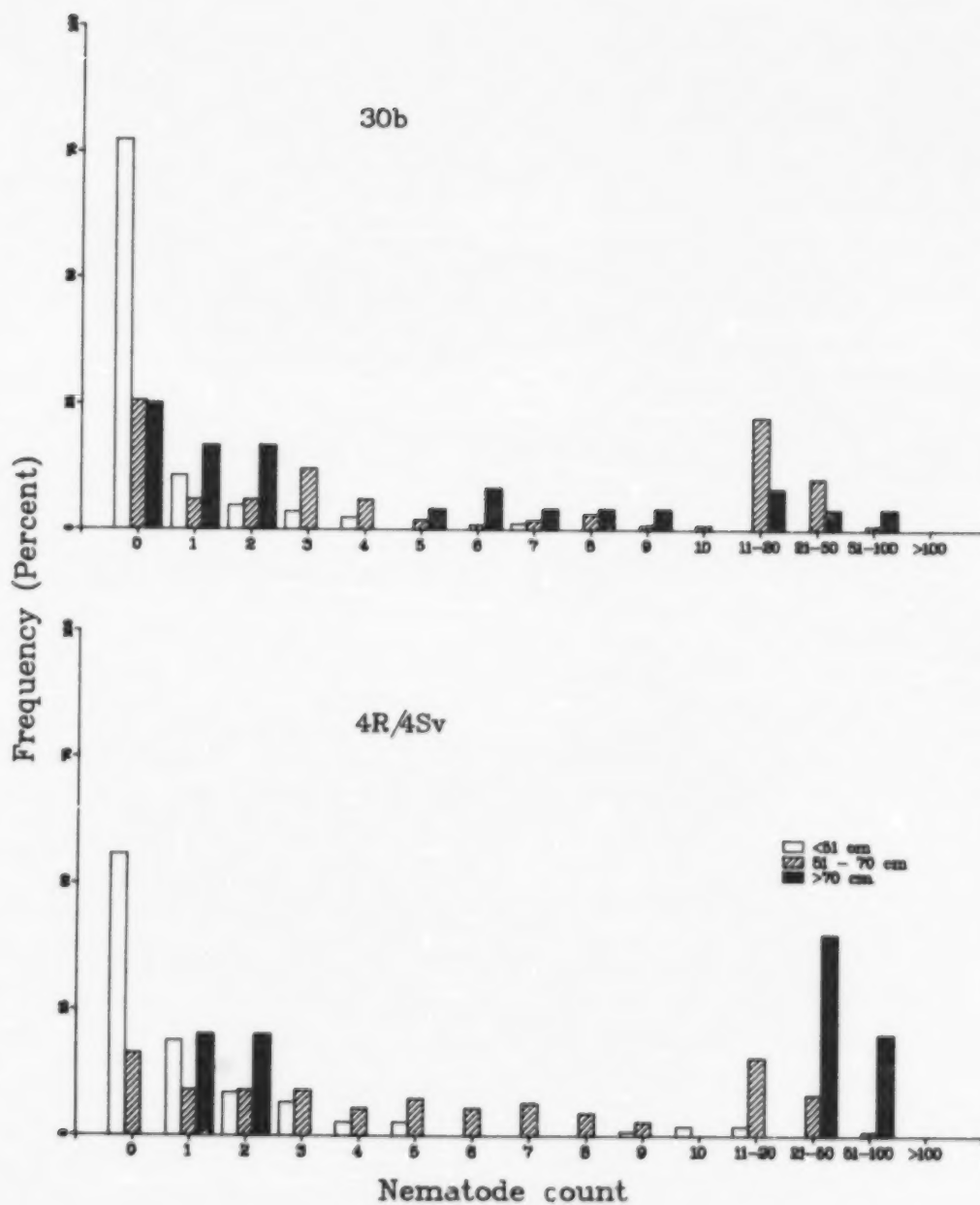


FIG. 8. Frequency distributions of *C. osculatum* larvae in cod from Whale Bank (30b) and the northeastern Gulf of St. Lawrence (4R-4Sv): distributions for <51, 51-70 and >70 cm host length strata.

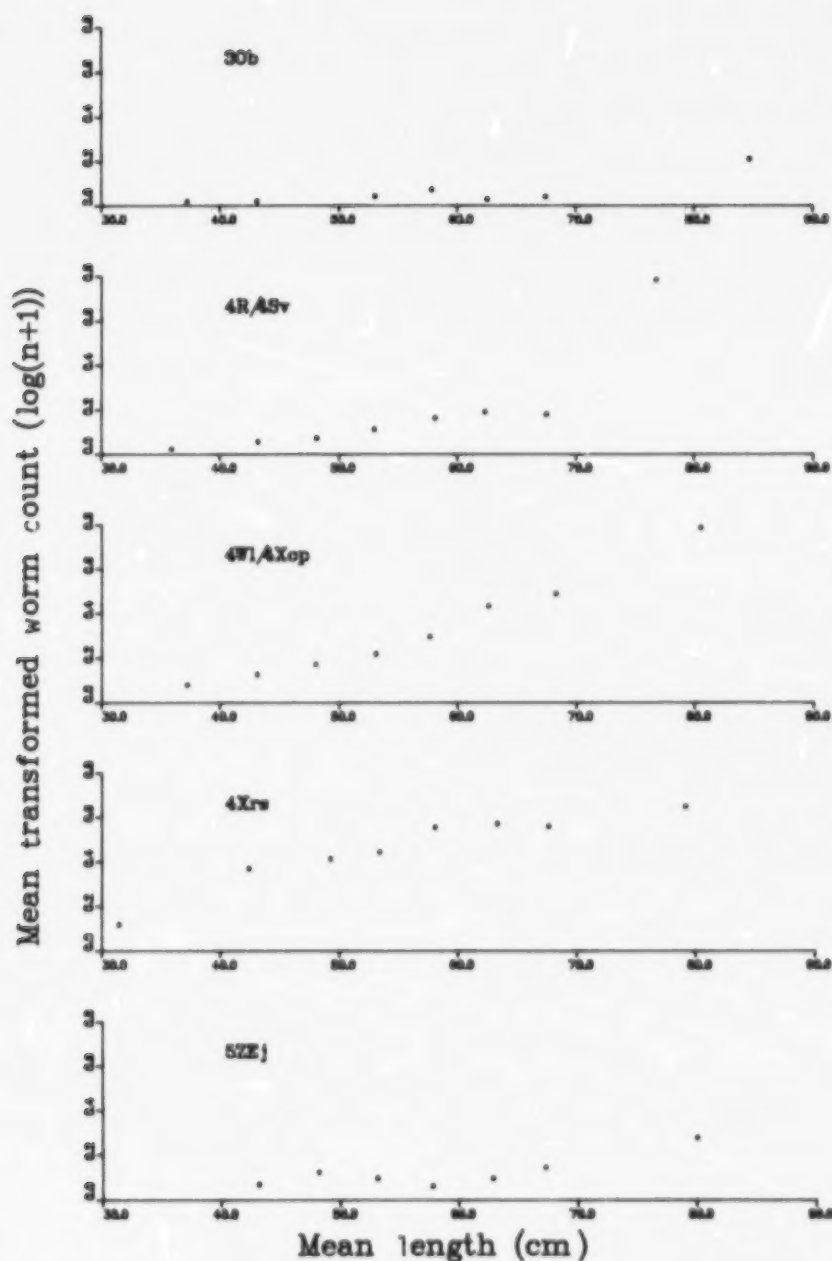


FIG. 9. Mean transformed sealworm (*P. decipiens*) count versus mean host length for 5-cm length strata (≤ 30 , 31-35, 36-40, ... ≥ 71 cm) of 30b, 4R-4Sv, 4W1-4X and 5ZEj cod.

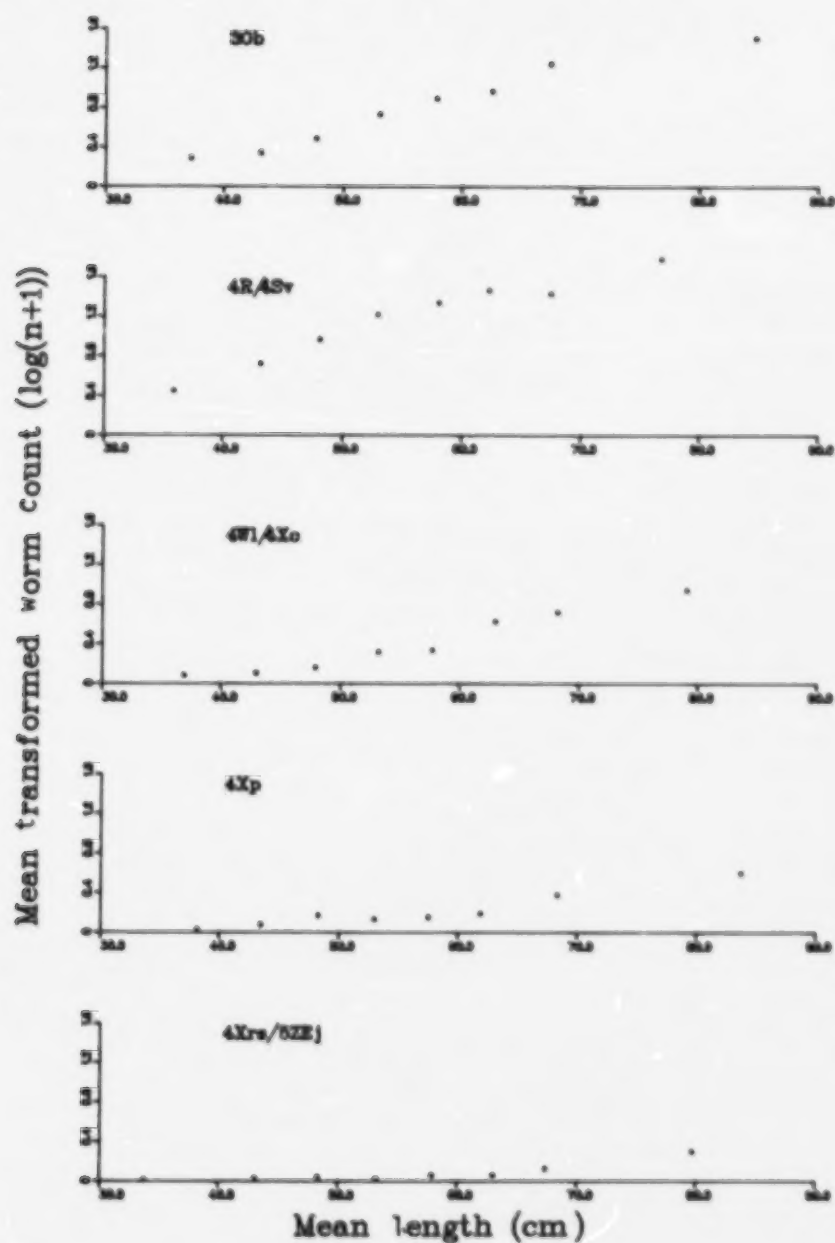


FIG. 10. Mean transformed counts of *A. simplex* larvae versus mean host length for 5-cm length strata of 30b, 4R-4Sv, 4W1-4X and 5ZEj cod.

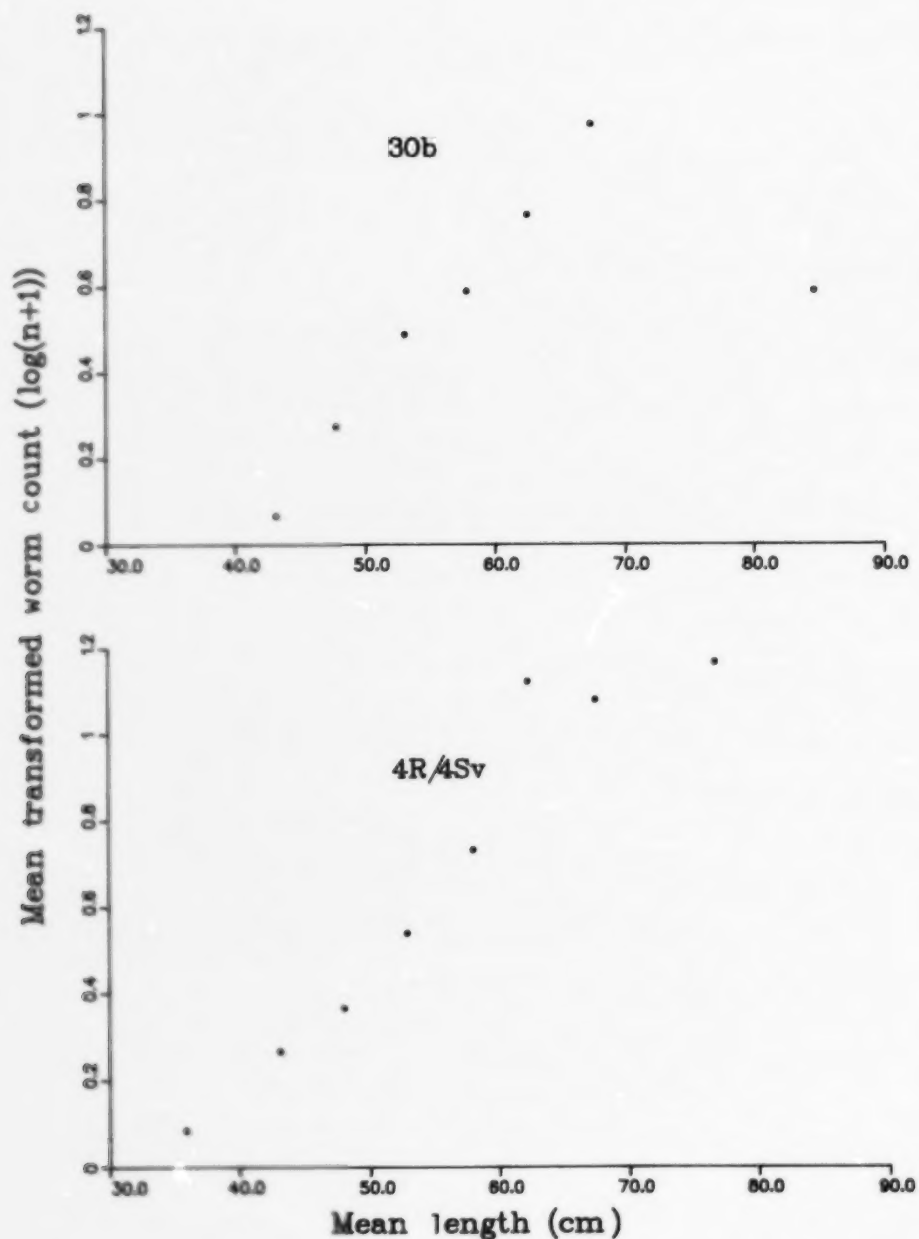


FIG. 11. Mean transformed count of *C. osculatum* larvae versus mean host length for 5-cm length strata of 30b and 4R-4Sv cod.

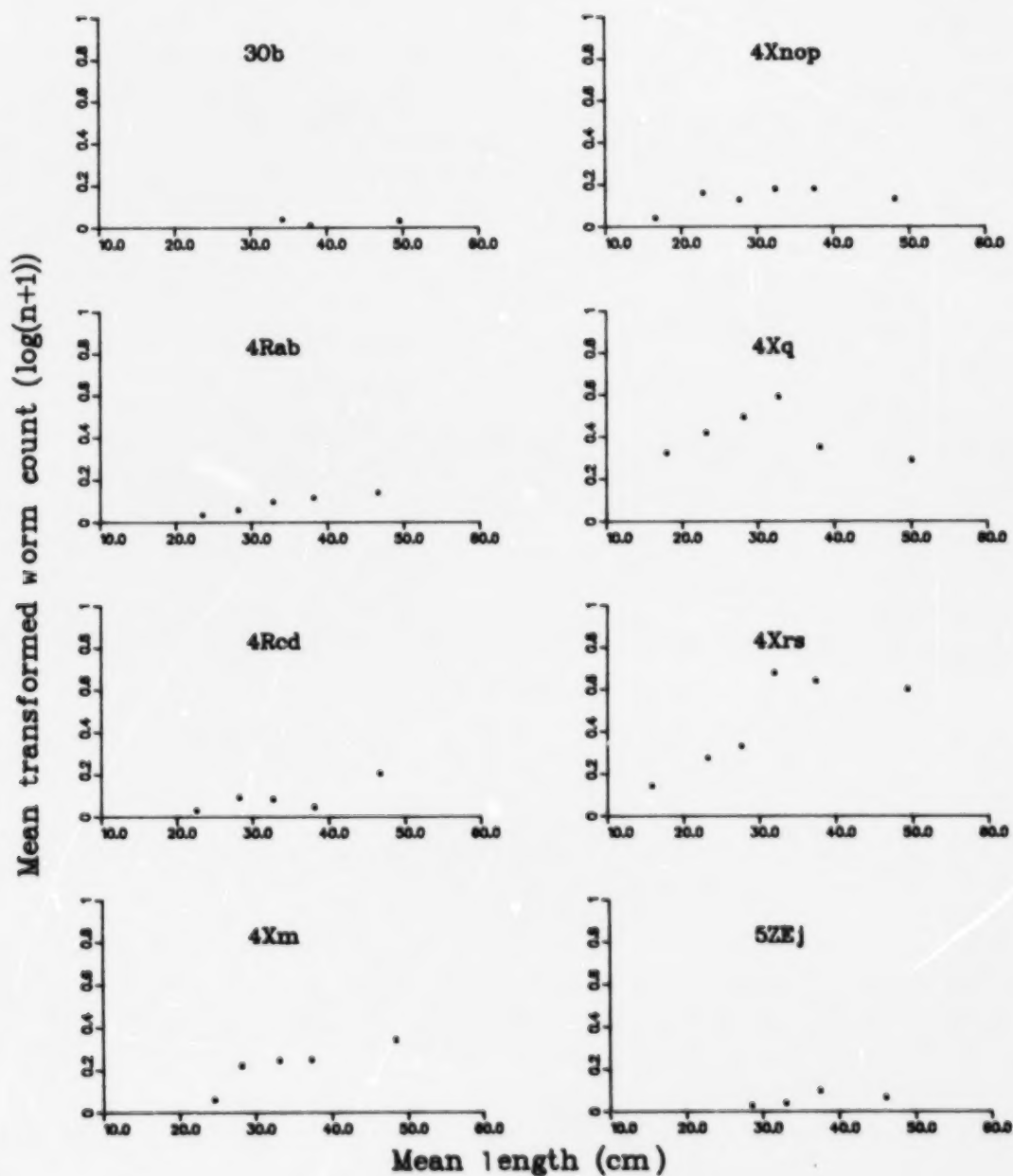


FIG. 13. Mean transformed sealworm (*P. decipiens*) count versus mean host length for 5-cm length strata of American plaice from Whale Bank (30b), the northeastern Gulf of St. Lawrence (4R) and southwestern Nova Scotia (4X-5ZEj).

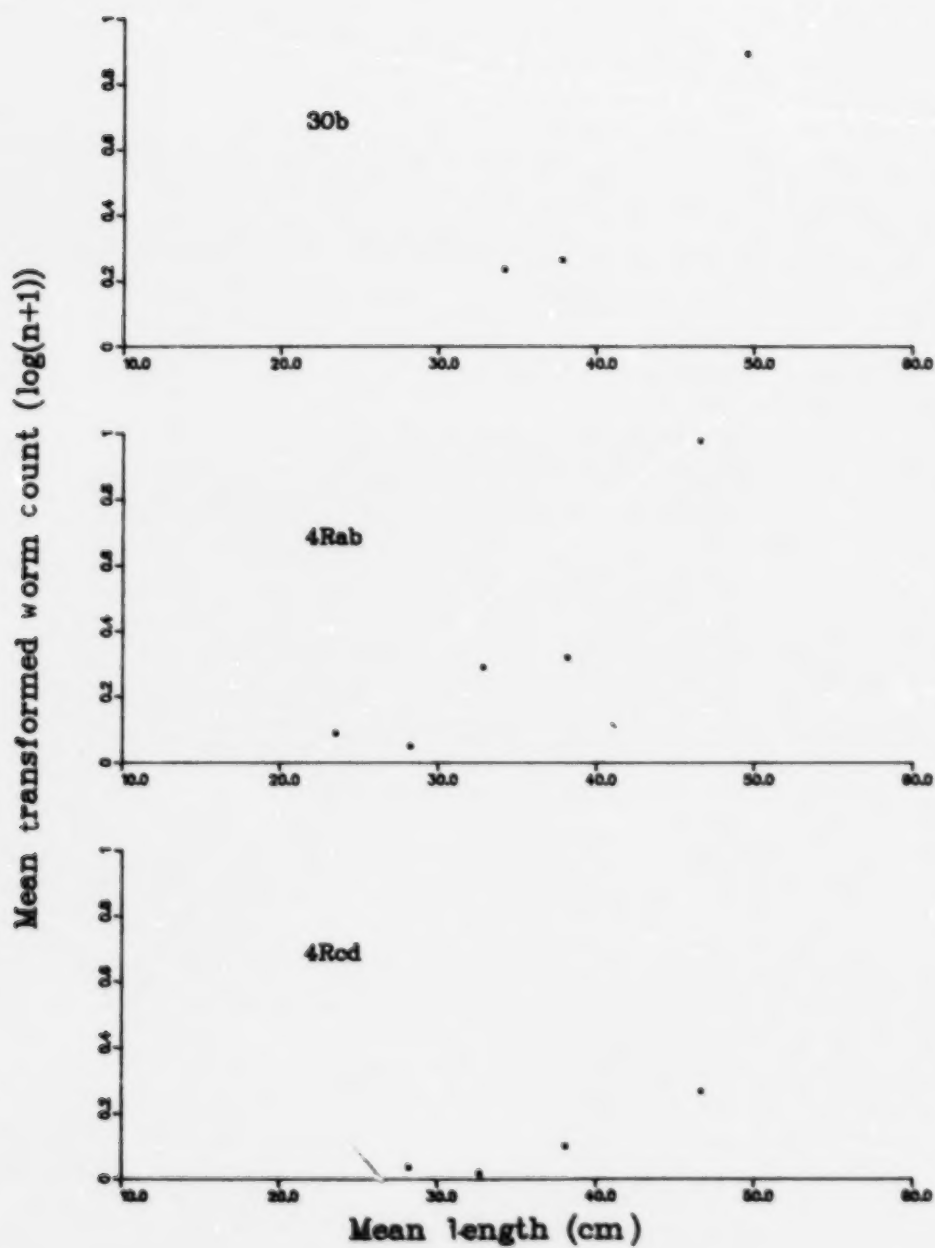


FIG. 14. Mean transformed count of *A. simplex* larvae versus mean host length for 5-cm length strata of American plaice from Whale Bank (30b) and the northeastern Gulf of St. Lawrence (4R).

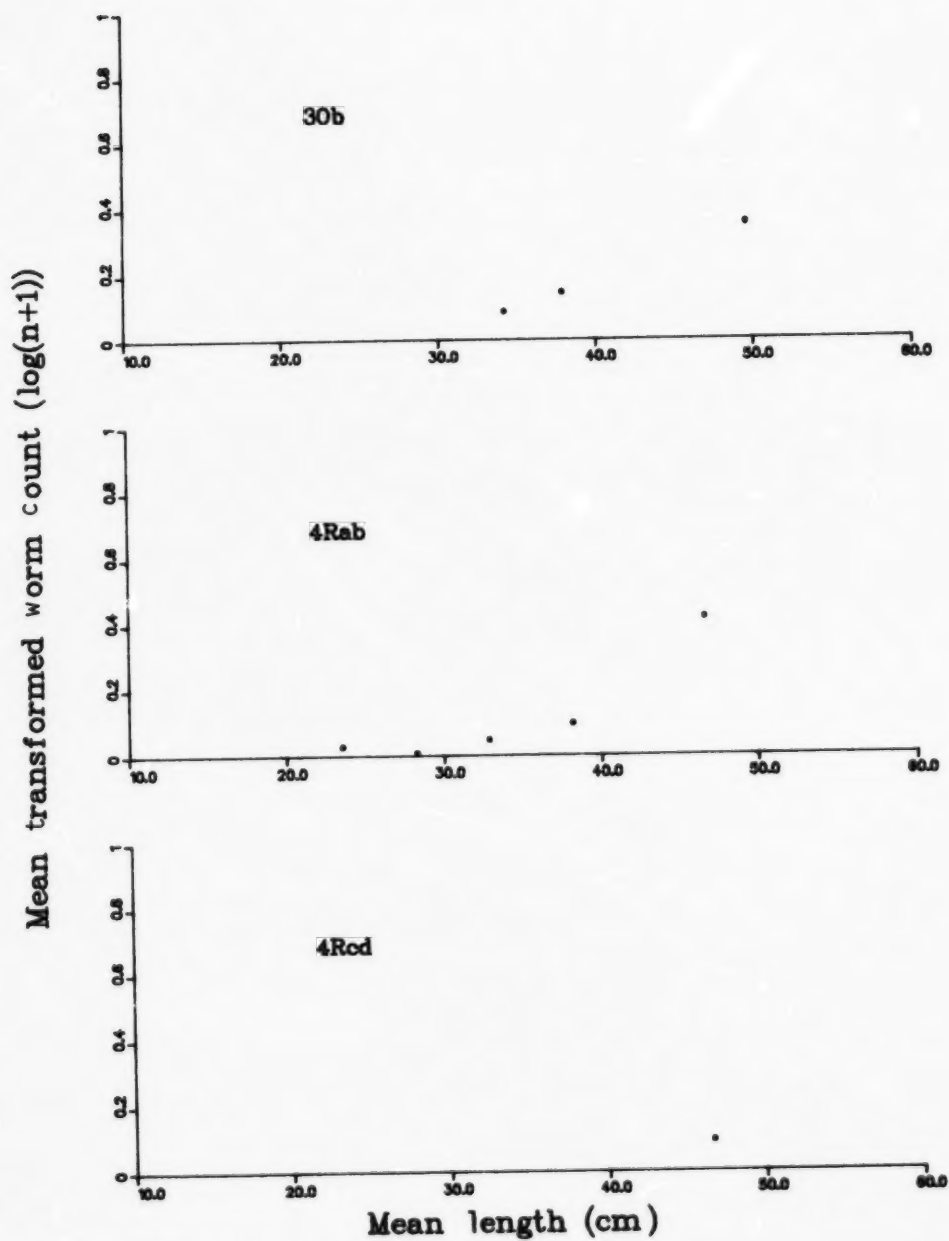


FIG. 15. Mean transformed count of *C. osculatum* larvae versus mean host length for 5-cm length strata of American plaice from Whale Bank (30b) and the northeastern Gulf of St. Lawrence (4R).

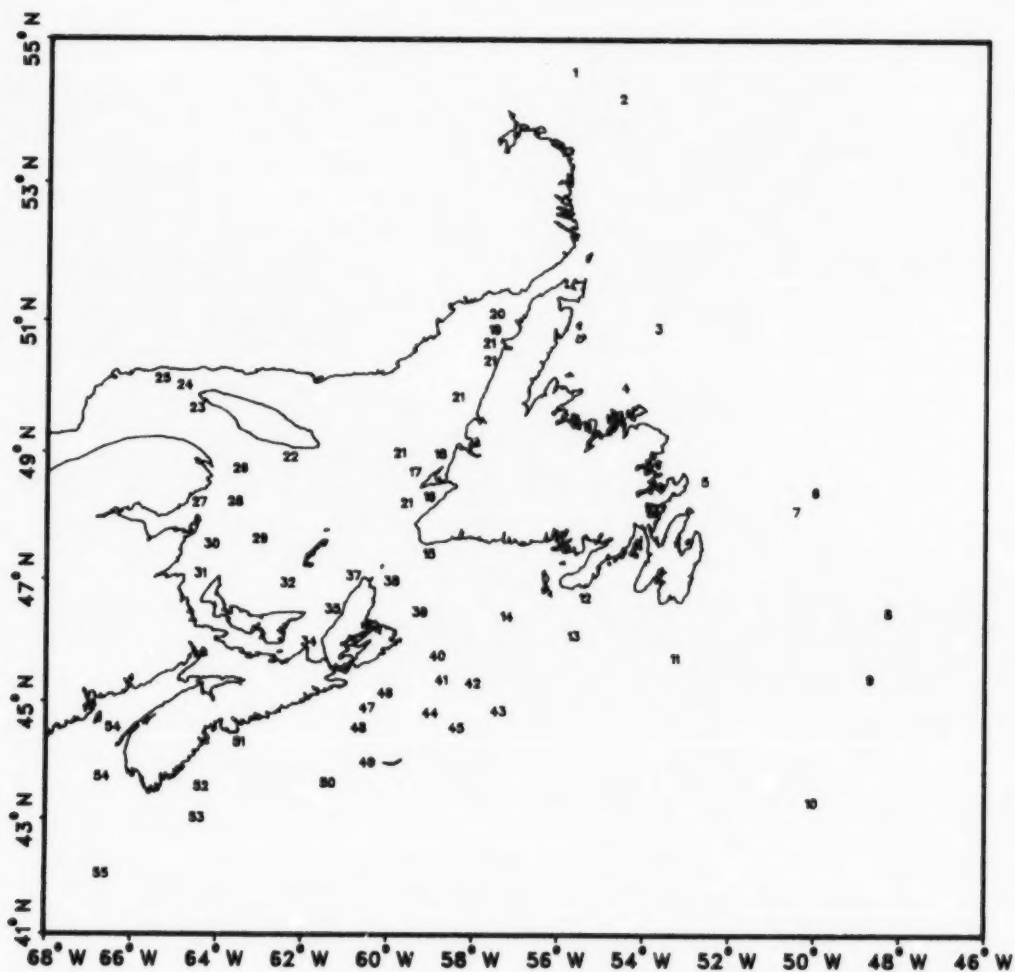


FIG. 16. Sampling locations for American plaice, 31 cm-40 cm in length, 1983-84.

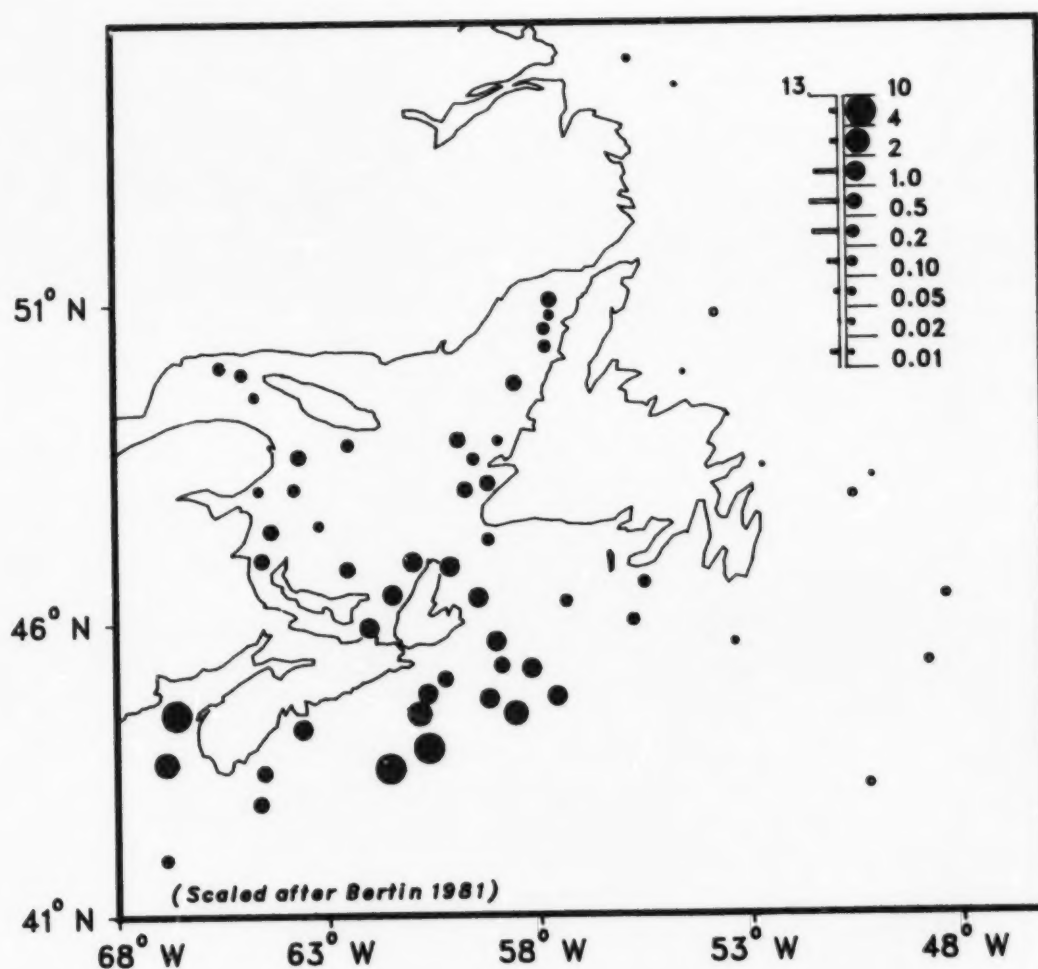


FIG. 17. Geographical variations in sealworm (*P. decipiens*) abundance in the fillets of American plaice, 31 cm–40 cm in length, from eastern Canada, 1983–84. (Diameters of symbols scaled according to nematode abundances; frequency distribution of fish by nematode abundance also indicated on scale; [o]=sealworm not detected.)

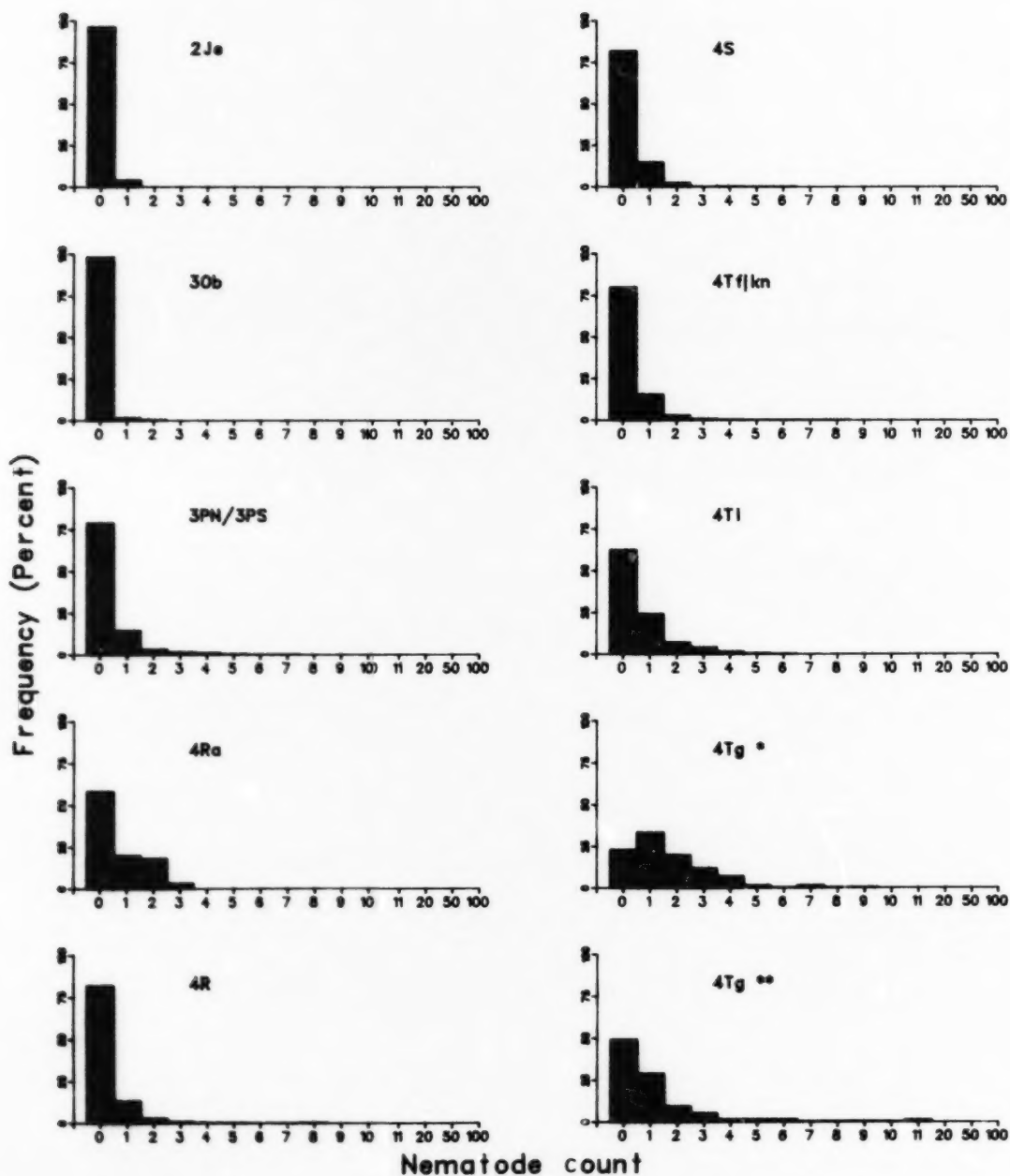


FIG. 18. Frequency distributions of sealworm (*P. decipiens*) counts in the fillets of American plaice, 31 cm-40 cm in length, from eastern Canada, 1983-84.

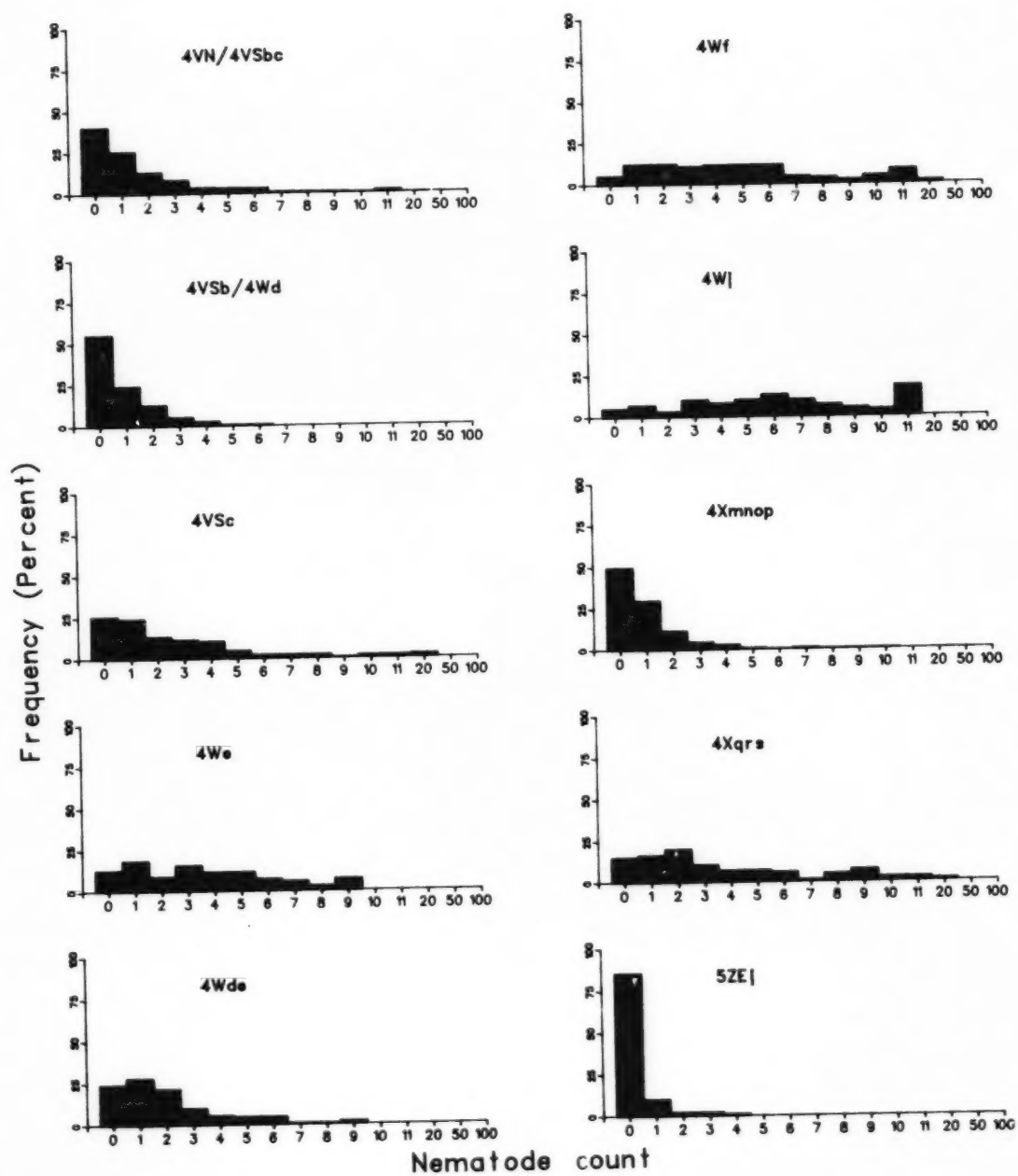


FIG. 18. (continued)

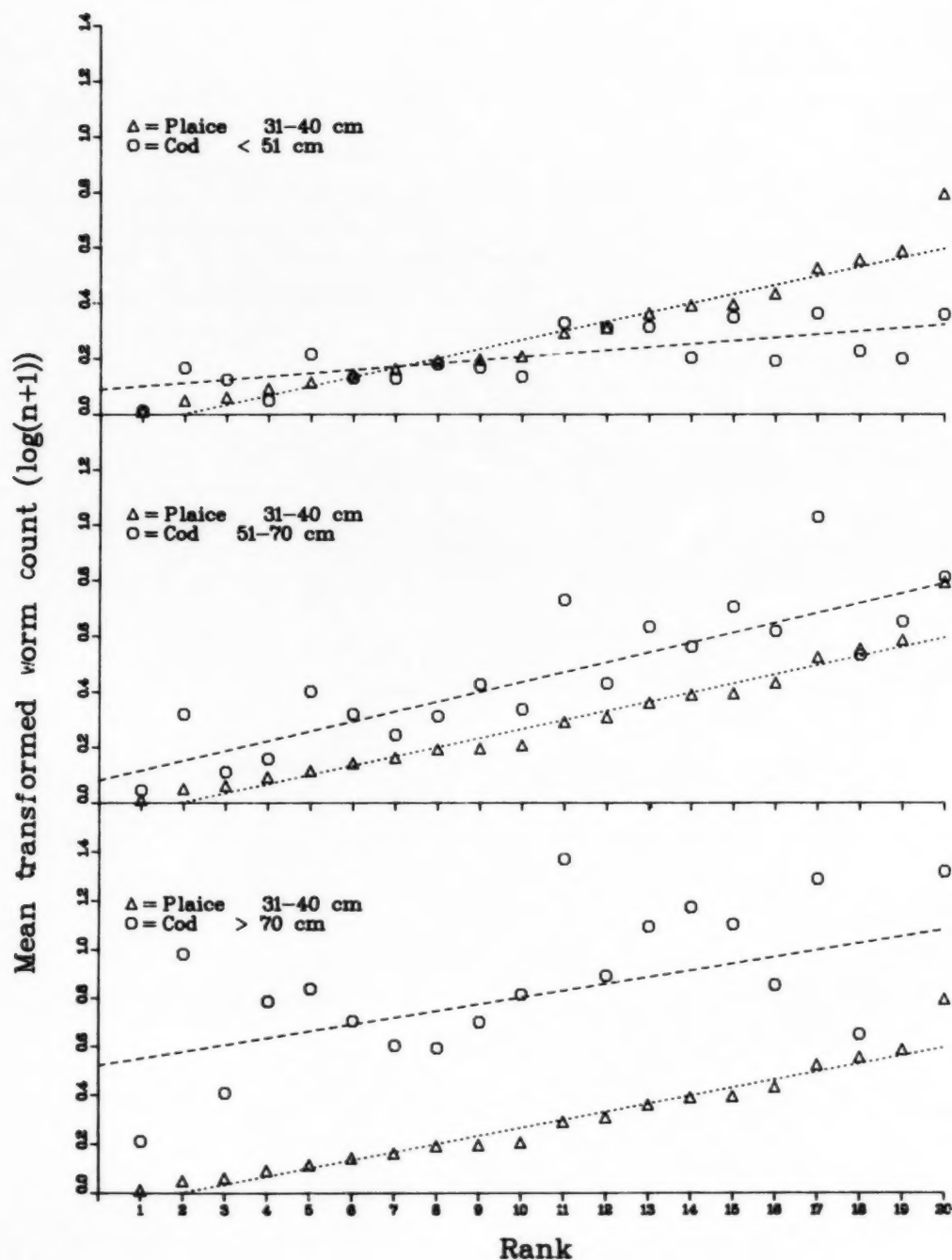


FIG. 19. Weighted regressions of transformed sealworm (*P. decipiens*) count on sample rank for plaice 31-40 cm in length and cod < 51, 51-70 and > 70 cm in length. (Samples ranked in ascending order of mean transformed worm counts in 31-cm to 40-cm plaice. See table 17.)

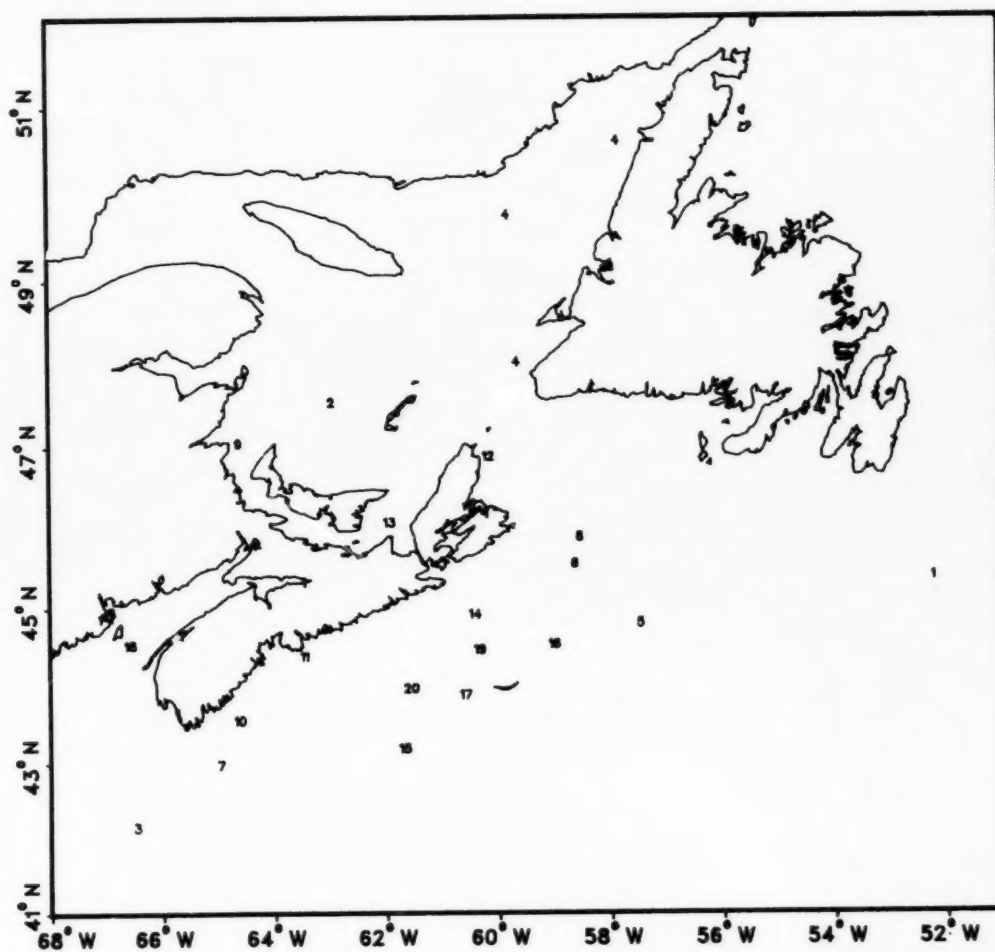


FIG. 20. Locations of paired samples of cod and plaice, 1980-84, ranked in ascending order of mean transformed sealworm counts in 31-cm to 40-cm plaice. (See Table 17.)

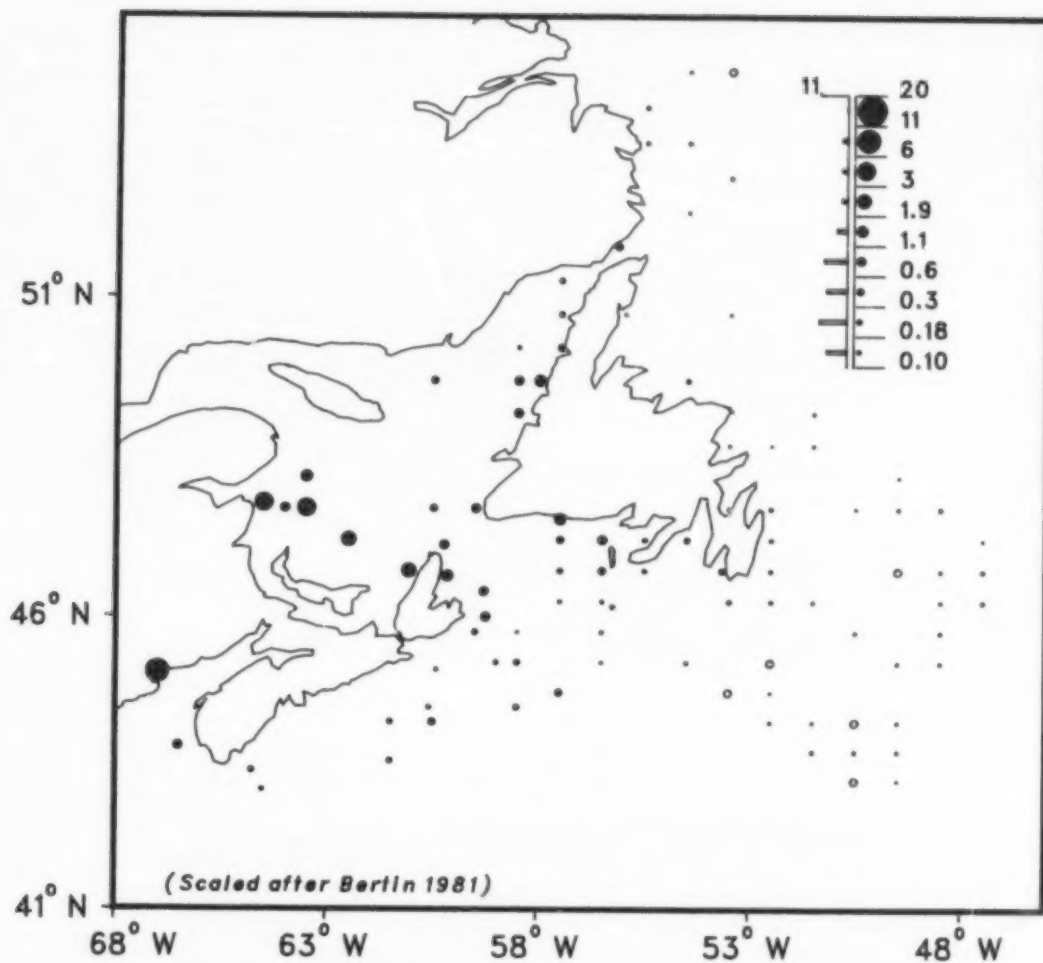


FIG. 21. Geographic variations in abundance of larval anisakines (*P. decipiens* and *A. simplex*) in the fillets of eastern Canadian cod ≥ 41 cm in length (1946-56). (Data from Scott & Martin [1957] and Templeman et al. [1957]; diameters of symbols scaled according to nematode abundance; [o] worm-free samples.)

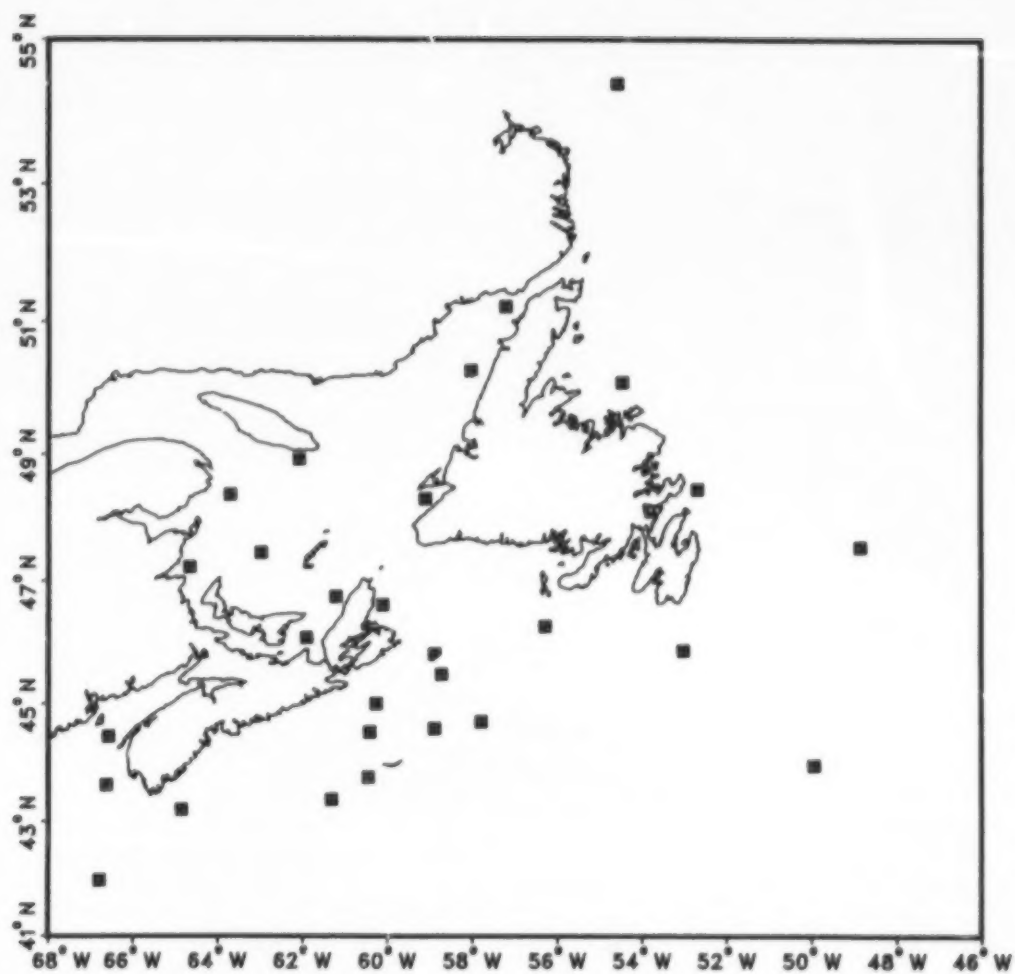


FIG. 22. Tentative sampling locations for future surveys of sealworm abundance in American plaice, 31 cm–40 cm length range.

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